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CIS

ALTERNATIVE FUELS FOR GENERAL AVIATION

HEARING

BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION,
AVIATION, AND MATERIALS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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CONTENTS

WITNESSES

August 28, 1983: Page
- Joe D. Hall, Deputy Assistant Secretary (Acting) for Conservation, Department of Energy; accompanied by Gene Eckland 3
- Roy Adkins, director of programs, alternative energy division, Beech Aircraft Corp., Wichita, Kans., accompanied by Harry Magri, flight test pilot; and Harry Ziesloft, chief engineer for research, Experimental Aircraft Association, Hales Corners, Wis 23
- William C. Paynter, president, Union Flights, Sacramento, Calif., accompanied by Gordon Cooper, technical consultant; Robert L. Donahue, director, division of aeronautics, Illinois Department of Transportation, Springfield, Ill., accompanied by Larry Platt, chief, Bureau of Aircraft Maintenance for the State of Illinois and David Lewis, deputy director; and Dr. Max Shauck, Baylor University, Waco, Tex 133
- Murray Smith, Director, Central Region, Federal Aviation Administration; accompanied by Barry Clements, manager of Aircraft Certification Division for the Small Airplane Division in Kansas City, and Martin Lindenauer, representing the Engine Certification Director; and Thomas J. Smith, chairman, energy committee, General Aviation Manufacturers Association 159
- William J. Wells, III, assistant manager, new product development, Celanese Chemical Co., Dallas, Tex.; and J. Robert Wade, president, Kentucky Agricultural Energy Corp., Franklin, Ky 186

APPENDIX

Statement of Lawrence L. Burian, president, National Air Transportation Association 209

Statement of Mark Schrock, assistant professor, department of agricultural engineering, Kansas State University 211

ALTERNATIVE FUELS FOR GENERAL AVIATION

MONDAY, AUGUST 29, 1983

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS,
Washington, D.C.

The subcommittee met, pursuant to call, at 9 a.m., in the O. A. Beech Gallery, Beechcraft Activity Center, 9709 East Central, Wichita, Kans., Hon. Dan Glickman (chairman of the subcommittee) presiding.

Present: Representatives Glickman and Carney.

Mr. GLICKMAN. Good morning. I think it's useful to begin on time and try to give you as much time as possible to provide necessary information to the committee and to the Congress on the subject of the hearings today.

I would mention just a couple of things before I give an opening statement and turn the floor over to my colleague, Congressman Carney from New York. First of all, I want to thank Beech Aircraft Corp. for the use of this facility. This is as fine a facility as any place in the country for a hearing, and in addition to that, they have been most kind in providing coffee and fattening things like rolls, and I understand that if we don't eat the rolls we are going to put them in some sort of chemical process and turn it into fuel. So, I'm just kidding about that in case anybody thinks I'm serious, but we are very pleased that the hearing could be held today.

In addition to that, we will be—we have many witnesses today. Without trying to shorten your testimony down, we would like for you to, if you feel comfortable, summarize your testimony so that there will be ample opportunity for questions and answers. All of your statements will appear in the record in their entirety, so to the extent that any of you feel that if your statements are rather long, if you can summarize them, it would probably be useful. If possible, we would like your formal testimony to be no longer than 10 minutes, 10 to 15 minutes, and then we'll be glad to put the entire statement in the record.

Today the Subcommittee on Transportation, Aviation and Materials will examine the potential of alternative fuels for general aviation.

The price and availability of fuel continues to be a major barrier to the free expansion of general aviation. Forecasters now predict that one severe fuel disruption can be expected to occur within the next 5 years, and that three such disruptions are expected within any 10-year period of time. Since civil aviation fuel represents only about 6 percent of the petroleum consumed in the United States, its production is severely impacted by fuel shortages. In the 10-year period of 1972 to 1982, aviation fuel prices rose 600 to 1,000 percent and fuel consumption became an even more dominant factor in aviation economics. Although this increase in fuel prices had a more severe impact on airlines, it has also slowed the demand for general aviation aircraft.

With sales of general aviation aircraft in a depressed state, the development of alternative fuels such as liquid methane, ethanol, methanol, and automobile gasoline can help spur that industry back to health and subsequently bring jobs back to thousands of Wichita aircraft employees who are unemployed, as well as other aircraft employees who are unemployed throughout the United States.

The subcommittee is particularly interested in the recent flight testing of these alternative fuels, and intends to examine in detail the opportunities they present. Independent test programs on these alternative fuels have reached the point where their preliminary technical feasibility has been established. The logical next step is to identify the appropriate followup tests and demonstrations, and to determine what role the Federal Government should play in assisting and coordinating these important projects.

In short, it is our hope that this hearing will contribute to the ongoing work in, first, determining the most promising candidates for alternative aviation fuels and, second, encouraging rapid progress in the development of these capabilities.

I want to thank the expert witnesses that have agreed to assist us today, and look forward to a productive hearing.

And now I would like to call on my very talented and creative ranking member, Congressman Bill Carney from New York State.

Mr. **Carney**. Thank you, Mr. Chairman. I would simply like to say that only in America, Congressmen attend two hearings before 9 o'clock in the morning, one on alternative fuels and one by the Kansas Independent Oil and Gas Association, so I think that it is a comment on the work that you are doing out here, Dan.

I join today in welcoming our distinguished witnesses before the Transportation, Aviation, and Materials Subcommittee. As you mentioned, price and availability of fuels is a major barrier to general aviation growth. However, what many of these alternative fuels will offer is flexibility. It is essential that we continue to produce fuel products that can be used in all general aviation aircraft, thus providing flexibility to the whole fleet.

We have had experience before with a shortfall of availability of fuels, and the general aviation industry was the one that was hurt most. They did not get the allocations from the Federal Government when the Federal Government felt it was prudent to allocate fuels during the fuel crisis, so to look for alternative methods to fuel the aviation fleet is a very prudent thing to do.

Pricing is another very important issue in this industry, and to get the industry back on its feet, back where it belongs as a major industry in the United States, we'll have to come up with answers to the fuel question.

I look forward to listening to our witnesses today and I think we would be best served by getting immediately to those expert witnesses.

Mr. GLICKMAN. Thank you, Bill, and our first witness is Mr. Joe Hall, Acting Deputy of Conservation for the Department of Energy. And I think, Joe, you are accompanied by Gene Eckland, who has a great deal of experience in dealing with this subcommittee on a variety of alternative fuel issues. So it is a pleasure to have you here, and please proceed.

STATEMENT OF JOE D. HALL, DEPUTY ASSISTANT SECRETARY (ACTING) FOR CONSERVATION, DEPARTMENT OF ENERGY, ACCOMPANIED BY GENE ECKLAND

Mr. HALL. Yes; I'm pleased that Gene could join us this morning. His history goes way back in the alcohol fuels utilization program, in fact he was in it from its formative days. I would like to say, Mr. Chairman, I would like to condense my testimony considerably. I have quite a lengthy statement; I understand there are copies here if anyone would be interested in looking at it, that traces the Department of Energy's role, shows their relevancy to other agencies and the private sector, and lists a number of forecasts of what we think will happen. I'd like to also commend those that will follow us; I look forward to this testimony very much.

We do a lot of research. We think we are involved in some meaningful activities, but where the rubber meets the road is in folks like we are going to hear from today, that are actually putting those things into use, and I'm excited about those uses and looking forward to their testimony. I do appreciate the opportunity to present the Department of Energy's views on alternative aviation fuels. A formal document has been submitted, as I said, and that addresses a multiplicity of issues and factors, including some pertinent technical material. In the interest of time I'd like to provide this very brief overview statement.

The Department of Energy and its predecessor organizations have sponsored research and development on processing and use of new fuels for many years, and further work is continuing. DOE first, and then the Synthetic Fuels Corporation have, provided funds and mechanisms, excuse me, for industry, to plan, evaluate and construct facilities to make a variety of fuels applicable to transportation use. These include ethanol, methanol and oil shale liquids. All of these are, or soon will be, available to commerce. Also methane, or natural gas, and other hydrocarbon gases such as propane have long been marketed. DOE has sponsored research and development on utilization technology for the application of these fuels, building a data base for alcohols, and filling the data gaps in the repertoire of gas use fuel technology. Jet fuels from oil shale crude have been and are being tested by the Air Force, and NASA is conducting some basic research and development in such fuels.

The Department of Energy Alternative Fuels Utilization program works cooperatively with both the Department of Defense and NASA, supplementing the work of those organizations by activities such as investigating coal products from syn crude refining in engines for highway vehicles. There is a common applicability of engine fundamentals to the engine and automotive sector. As a result, the comprehensive results available on use of alcohol fuels in automotive spark ignition engines are applicable to aircraft piston engines. Similarly, fundamental information on gas turbines is useful to designers of aviation, automotive and aircraft engines. As a corollary, unresolved problems such as absorbing water and cold start warmup deficiencies in methanol-fueled engines are pertinent to aircraft as well as automotive uses. Gaseous fuels such as methane have had sufficient attention over the years to provide a solid base for their use.

Assessments have been made for DOE on the overall applicability of alternative transportation fuels, and, from NASA on detailed factors pertinent to area of operations. The available information is considered sufficient for industry to make judgments on the use of its resources, whether for a product-based application or to fit an initial opportunity. It seems to us at DOE that industry would prefer to use fuels that emulate petroleum products. A major factor, that is energy density and ease of handling of such fuels, permits the use of existing equipment in retaining the payload and range of petroleum products.

Where economics and mission permit there is no known overriding reason why liquid methane and alcohols cannot or should not be used. This is a marketplace decision best resolved by industry.

In instances where the fuel is not a direct replacement for a petroleum product, one might well encounter a chicken or egg problem as related to the initiating the supply of fuel in the engine. Just as this obstacle stands before the automotive industry, investment and product costs are no small problem, as alternative fuels are typically at this time more expensive than those presently used.

In summary, Synthetic Fuels Corporation is continuing to work to encourage production of new fuels from indigenous resources. DOE is continuing to research and develop a new process and fundamentals of using new fuels in transportation, and the Department of Energy is continuing to cooperate with NASA, the Air Force, and other Department of Defense components on aviation-oriented fuel use technology. The aircraft industry will presumably address commercial applications that appear available, including its applications.

Thank you for this opportunity to present a brief overview of my long statement, Mr. Chairman. I'd be glad to try to answer any questions.

[The prepared statement of Mr. Hall follows:]

STATEMENT OF

MR. JOE D. HALL

DEPUTY ASSISTANT SECRETARY (ACTING) FOR CONSERVATION

DEPARTMENT OF ENERGY

Mr. Chairman and Members of the Subcommittee:

It gives me pleasure to provide you with information on the subject of alternative fuels for aviation use. I intend to briefly put the use of aviation fuel in perspective, outline the role of DOE in encouraging production of liquid substitutes for petroleum, identify the relationship of DOE to other Federal agencies in advancing aviation fuels utilization technology, and describe some major technical facets of using alternative fuels in aviation. Since the technology for use of fuels in aviation is closely related to that for use in highway vehicles, the applicability of DOE work in the latter will be noted.

In the United States, transportation uses about 58 percent of the total petroleum consumed. Civilian aviation uses about 7.8 percent of the total petroleum energy used in transportation. This is made up of 6.2 percent by domestic air carriers, 0.7 percent by international air carriers, and 0.9 percent by general aviation, air taxi and commuter air carriers. Including the military, about 10 percent of the petroleum used in transportation is jet fuel and about 0.5 percent* is aviation gasoline (avgas). Aviation fuel costs have substantially increased in recent years, just as they have in other sectors. In commercial aviation transport, fuel costs have increased from about 25 percent of total direct operating costs in 1973 to over 55 percent in 1981. This trend has had major impacts on commercial aviation. In general aviation, such costs may impact in a more emotional manner, but increased expenses are every bit as real. Figure 1 shows the general history of avgas prices, including a comparison to those of leaded regular motor gasoline (mogas).

In its programs the Department of Energy (DOE) continues to address both the supply and utilization sides of alternative fuels for transportation. In

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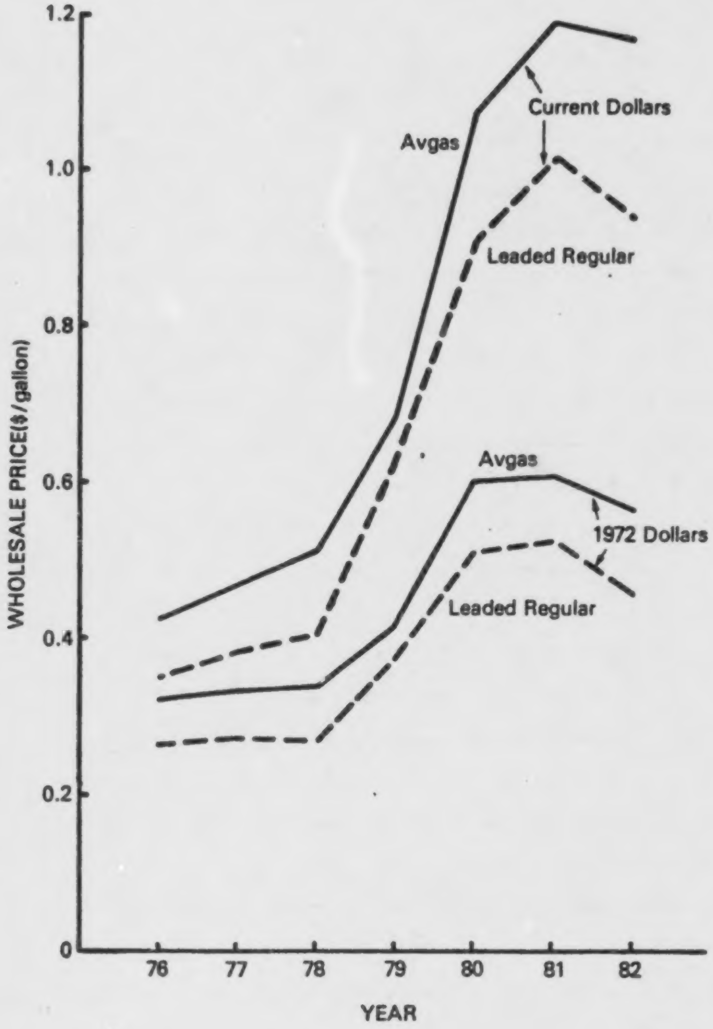
*About 500 million gallons.



Source: DOE/EIA 1982 Annual Energy Review

Fig. 1. General history of recent avgas prices with comparison to that of regular gasoline.

addition to sponsoring R&D in technologies for processing fossil fuel and biomass feedstocks, DOE played a role in encouraging private sector production of such fuels. For example, under Public Law 96-126, the DOE Alternative Fuels Production Program funded forty seven (47) alcohol fuel feasibility study grants and three (3) alcohol fuel cooperative agreements. All of the former, at a cost to the government of $21 million, were successfully completed. As of February 1, 1983, fourteen (14) of the grantees were continuing to pursue construction of a facility, while the others were dormant due to lack of financing. The three projects pursued under cooperative agreements will produce 91 million gallons of ethanol per year upon completion. Two of the plants are operating, and the third (10 million gallons/year) is scheduled for start-up late this year. The government's share of cost for these plants was $37 million. Eighteen (18) studies were funded in the amount of about $44 million to determine the feasibility of gasifying or (indirectly) liquefying coal. Four other studies, amounting to about $3.9 million in government support, addressed recovery of natural gas from unconventional resources. Four (4) oil shale feasibility studies were initiated with three completed (at a cost of just under $7 million) and the other cancelled. Of the twenty-three (23) synthetic fuels projects under consideration by the Synthetic Fuels Corporation (SFC) on June 30, 1983, eighteen (18) addressed transportation fuel needs. Three of the projects (First Colony, Keystone and North Alabama) would produce methanol from either peat or coal.

Returning to aviation interests in fuels use, engine types used to propel aircraft are primarily the internal combustion type for piston engine light aircraft and the gas turbine type for larger aircraft. Due to the desire for a high horsepower-to-weight ratio, the light-aircraft engines are spark ignited rather than compression-ignited (diesel). Relatively high compression engines are used to give high output power and efficiency, and these require gasoline with a very high octane rating (characteristic of aviation gasoline). Larger, higher-speed aircraft use gas turbine engines. These use distillate fuels usually approximating kerosene, having a relatively wide boiling range. Commercial fuels are termed Jet A, while military fuels have various JP designations typically ranging from JP-4 (the most prevalent) through JP-8. In all cases in aviation the fuel characteristics and engine design features have been carefully matched, just as they have with engines for automobiles and other highway and off-highway vehicles. Therefore, some alternative fuels make more sense in some applications than in others. Table 1 provides a broad overview of fuels applicability to Transportation equipment.

The DOE Office of Vehicle and Engine R&D (VERD) philosophy on transportation energy activities has been to work in areas of greatest potential impact as long as they do not duplicate or impinge on private sector R&D efforts, or on the charter of other federal agencies which have established and traditional roles. Major transportation use of energy, in the form of petroleum products, is by highway vehicles. As such, this sector is the primary focal point for VERD work. Where other agencies play a key technical role (such as the National Aeronautics and Space Administration [NASA] for aircraft, Federal Railroad Administration for rail, and Maritime Administration for marine transport), DOE plays a cooperative role, devoting attention to any energy-related information or technology gaps, as applicable. For aircraft (and other transport modes), VERD has assessed the potential for substituting alternatives to petroleum, taking into account the total system ramifications from resource through end use, including emissions aspects. This assessment shows that the most logical substitutes for petroleum products are fuels from so-called synthetic crude oils. The military is conducting technical R&D in this area, and cooper-

Table 1. Basic Potential Suitability of Alternative Fuels to Transportation Equipment

	Intermittent Combustion			Continuous Combustion	
Fuel	Otto (Spark)	Stratified Charge	Diesel (Comp.)	Brayton (Turbine)	Stirling
Gasoline					
Mogas	B(h,o)*	B(h,o)*		B(h)*	B(h)*
Avgas	B(a)*				
Distillate					
Diesel		n(h,o)	B(h,m,o,r)*	B(h,r)*	B(h,o)
Jet				B(a)*	
Synfuels					
Gasoline	B(h,o)	B(h,o)		B(h)	B(h)
Diesel		n(h,o)	B(h,m,o,r)	B(h,r)	B(h,o)
Wide cut		B(h,o)		B(h)	B(h,o)
Jet				B(a)	B(h,o)
Min. upgrade			B(h,m,o,r)	B(h,r)	B(h,o)
Alcohol fuels					
Straight	B(h,o);n(a)*	B(h,o)	n(o)	B(h)	B(h,o)
Blend	B(h,o)*	B(h,o)	n(o)	B(h)	B(h,o)
Gaseous fuels					
LPG	B(h,o)*	B(h,o)	n(o,r)	B(h,r)	B(h,o)
Methane	B(h,o)*	B(h,o)	n(o,r)	B(h,r);n(a)	B(h,o)
Hydrogen	B(h,o)*	B(h,o,r)	n(o,r)	B(h,r,a)	B(h,o)

Symbols

B	basic suitability
n	possible niche applications
(a)	aircraft
(h)	highway vehicles
(m)	marine
(o)	off-highway
(r)	rail
*	substantial technical data available

ative links between agencies are well established. For example, since refiners make a variety of products from a common feedstock, the Alternative Fuels Utilization Program (AFUP) activities include testing diesel fuels obtained from the same refinery run producing jet fuel for Air Force experimental tests. Results of the aircraft engine work are also reviewed. Civil aviation aspects are covered through similar interfaces and/or cooperation with NASA. Contact is also maintained with the Federal Aviation Administration of the Department of Transportation.

With the advent of alternative fuels, it has become somewhat popular to talk about multi-fuel engines. Experts in the engines/fuels field take exception to such terminology as being misleading. Some engines are more tolerant of varying fuel characteristics than others. Even here, one must be careful in defining the boundaries. Many engines will run on a wide range of fuels, and such has often been physically exhibited. However, an engine typically performs effectively only on fuels having limited variations in terms of fuel specifications from that fuel for which it was designed. Some engine types can be adjusted more readily than others to accommodate a different fuel. Beyond this, minor or modest design changes can theoretically be incorporated more readily in some engines than others. Therefore, some engines can, in principle, be adapted more readily than others to a multiplicity of fuels. The common automotive open-chamber, homogeneous-charge, spark-ignition engine is, for example, one type that offers ready adjustment of a number of parameters to accommodate, or to optimize performance with, varying fuels, providing those fuels have a low viscosity and a high octane rating. Thus spark-ignition engines used in most automobiles and general aviation aircraft can be adapted to effectively use gasoline, alcohol fuels, hydrocarbon gaseous fuels, and even hydrogen, but cannot use more viscous fuels. However, commercialization of engines to use such fuels will require significant design changes in order to offer appropriate performance, reliability and cost. Engines using more viscous fuels, namely petroleum distillates such as Jet A, use spray nozzles (also called injectors) to atomize and partially vaporize the fuel as it enters the combustion chamber. Here it is important that the fuels used are of similar viscosity or it becomes necessary to redesign the injector nozzle. Combustion must take place in a limited zone or else heat transfer and possibly other characteristics will be affected. If the engine is of an intermittent combustion type, such as the diesel engine, ignition or knock related characteristics (e.g., cetane rating) are important. In continuous-combustion engines of the gas turbine type, heat transfer characteristics are a key factor in performance and engine life, and are affected by the hydrogen-to-carbon ratio of the fuel. The carbon content of a fuel causes radiant heat transfer to the engine combustion chamber liner and the higher the carbon content the greater the liner temperature and the shorter its life. For this and other reasons, present engine designs are sensitive to hydrogen deficient fuels, which is the chemical direction suggested when considering synfuels. Hydrogenation of crude oils is costly in both economic and energy terms, and the need increases as one moves from petroleum to oil shale to coal. Examining other alternatives, both methane and methanol have a high hydrogen to carbon ratio and are suitable for gas turbine use in this regard.

For all engine types, appreciable attention must be given to compatability between the materials used in the fuel/engine system and the chemical characteristics of the fuel. These considerations hold true whether the fuel is petroleum based or an alternative.

Safety is another key factor in the use of alternative fuels for aircraft. Various limiting criteria must be satisfied if a fuel is to be accepted in the intended environment, and some of these are difficult to assure except on the basis of substantial statistical success. The considerable number of possible permutations of related factors provide a significant mental barrier to widespread acceptance of a new fuel and hence to an appropriate related investment climate. Thus, due to uncertainties in use of other fuels, petroleum and petroleum-like aircraft fuels enjoy a substantial advantage at this point in development and use.

Other factors of considerable importance are systems factors, such as energy use, convenience, technical maturity, environment-degrading effects, national security, and economics. Within this context, the specific nature of the commercial aviation application plays a substantive role.

Due to these various factors, R&D on alternative transportation fuels has included investigation of potential revolutionary changes in automotive fuel/engine systems while R&D in the aircraft area have largely been limited to evolutionary changes. The differences in these approaches may be primarily related to the costs of such investigation. For the most part, R&D on a revolutionary fuel/engine system related to a spark-ignition reciprocating engine can be done far more economically than for, say, a gas turbine engine. A review of funding histories in this field suggests that work to date has been concentrated on those areas where the important effects of alternative fuel use can be assessed at very modest costs.

Among the reasons for using petroleum almost exclusively as the fuel for transportation are its ease of handling and its high volumetric energy density. Potential substitute fuels other than those that emulate petroleum typically have a lower volumetric energy density, require a larger storage system, and/or weigh more on a total fuel/ container system basis. Aircraft manufacturers have two major concerns that relate to these aspects: payload and range.

Principally because of these factors, aircraft engine and airframe manufacturers opt for fuels with characteristics like those now in use. Aircraft being sold today will probably be used for another 30 years, and the manufacturer is not likely to confuse a prospective customer with information on different future fuels. NASA activities are consistent with this industry view. Since characteristics of available crude oils are gradually changing to heavier material (lower hydrogen-to-carbon ratio) and oil shale crudes are similarly constituted, NASA earlier planned a project to investigate jet fuels with a modest change in a few related characteristics. This plan, worked out technically and through priority reviews over a couple of years, was costed at something over $100 million dollars spread out over several years. From this figure it is obvious that where R&D on alternative fuels involves more than a modicum of engine work, the activities are expensive, and candidate fuel/engine systems must be evaluated as to priority of attention.

The Air Force, which acts as the design sponsor, purchaser, and user of aircraft and engines, is putting considerably more effort than the civil sector on the future fuel characteristics that differ from those of current fuels, and has a test program to look at limit conditions of hydrocarbon fuels that might influence fuel/engine tradeoffs in the next generation of combat aircraft. DOE/AFUP personnel and specialists from other Federal agencies involved in mobility end-use R&D have long worked together to find a mechanism to obtain test synfuels with appropriate characteristics so as to develop essential data of the type the Air Force needs. The AFUP has contributed to an assessment for the Air Force by a special committee of the National Research Council on the need for a national or Department of Defense facility to process such test fuels from synthetic crudes in the large quantities necessary for meaningful development tests. Being faced with similar problems on a much smaller scale, the AFUP will soon have a capability (less than one barrel per day) in place* to provide test fuels to its projects, to industry and to other agencies. With this facility, it should be possible to start a synfuels data base and build on it over the next few years. With time, data from both the civil and military activities should provide a feel for how appropriate it is to use synfuels in contemporary engines and what favorable impacts on synfuels processing can be achieved through reasonable changes in engine design.

Although the AFUP list of priorities favors fuels from synthetic crude oils, and work has started on developing a data base for these, the program includes other identified options such as alcohols. The goal is to achieve technical commercial readiness of various fuel/engine combinations selected as the most logical major contributors leading to replacement of petroleum. Initial priorities concentrated on fuels from indigenous abundant, or renewable non-petroleum resources. Natural gas was included with petroleum as endangered, precious fuels, and thus only substitutes were initially included. However, since conservation and fuel switching practices have substantially reduced demand for natural gas (methane) and a surplus supply is presently available, the Congress has expressed the view that this fuel can help reduce crude oil demand in the general transitional phasing to as yet undetermined future transportation fuels. Thus R&D on methane is now a part of AFUP activities. The AFUP periodically reviews the state-of-the-art/knowledge of these options to determine the remaining problems and data gaps which need to be resolved. This review thereby provides a focus for future R&D by the U.S. Government and private industry.

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*At the Southwest Research Institute, San Antonio (a non-profit organization) at a locale adjacent to the Army Fuels and Lubricants Research Laboratory.

For any given potential alternative fuel, there are both those applications that offer the maximum benefits and greatest market potential and other special applications possibilities. The latter include niche situations where unique circumstances mitigate some of the disadvantages normally encountered. Individuals are often attracted to these, and many enthusiasts actively promote them. An example is the use of alcohols in both reciprocating and turbine aircraft engines. The relatively low energy density of alcohols, particularly methanol, as compared to petroleum products detracts from the aircraft payload and range characteristics important to the aircraft marketer. Yet, in some applications, the user may find that the penalties are inconsequential. The DOE views these factors as marketplace decisions that should be resolved by the private sector. Another example, which fits much the same situation, is the use of liquid methane in small aircraft. If the economics and mission ramifications make sense, there is no reason not to use liquid methane. On the other hand, sometimes regardless of the fuel, the cost/benefit characteristics of each fuel/use combination will differ, with some being logically better than others. It is not uncommon for proponents of a fuel to consider it without regard to competitive options, and/or to become convinced that their fuel of choice should be used in virtually all situations and applications. Although petroleum is used on a broad basis, the specific fuel products used in various engine types are distinctly different and not universally applicable. Similarly, alternative fuels are unlikely to be universally suitable. The key to eventual success, then, is to solidly establish the fundamental data from which commercial enterprises can make appropriate business decisions. This data is basically available for the use of either alcohol fuel(s) or methane in homogeneous charge spark-ignition engines. Establishing appropriate data bases continues to be the thrust of the DOE AFUP.

Alcohol fuels can be, and have been, used experimentally in engines for light aircraft just as they have been in automobiles. The technical data and information base established for automotive powerplants (largely through DOE/AFUP sponsorship) is equally applicable to aircraft reciprocating engines. The differences that do exist between potential results in light aircraft and automobile applications are a matter of degree. It is probable that benefits of using alcohols are about the same for both modes. Unresolved problems, such as abnormal wear and cold start/warmup, apply to both applications. Appropriate preparation of the fuel charge and selection of both fuel system materials and delivery components need to be addressed in both highway vehicle and light aircraft use. In both cases, there appears to be a preference to use of methanol, largely due to the favorable fuel cost. The following remarks are based on using methanol, but are essentially applicable to ethanol as well.

Fuel economy, on an energy basis, is better with methanol than with gasoline. A few percent gain in thermal efficiency due to the fuel alone applies equally to both applications. When the engines are optimized for each fuel, improvement is probably comparable for automotive and aircraft applications, amounting to perhaps 20 to 25 percent, but for different reasons. A substantial improvement in both applications is due to increased engine compression ratio possible to the higher octane rating of methanol relative to gasoline. This gain may not be as beneficial to aircraft because high octane gasoline is already used in many aircraft. In automotive use, changes in the torque due to modified camshafts and revised rear axle ratios provide improvement not directly nor economically applicable to aircraft. Both automobiles and aircraft can achieve fuel savings by operating with a lean air-fuel mixture, and here the benefits can be greater in aircraft use than on the highway. In aviation, the pilot controls the air-fuel mixture. (This is mechanically or electronically scheduled in an automobile.) It has long been customary to operate piston aircraft engines fuel-rich in order to keep the engine temperature within specified limits and thereby enhance durability and reliability. Alcohols will burn with a very lean fuel component (i.e., with excess air) which along with the basic vaporization characteristic of alcohols, results in cooler combustion than with gasoline. Thus, under cruise conditions, a pilot can operate with a very lean alcohol mixture where a richer gasoline mixture would normally be used. Under lean burn conditions, the available power output of the engine decreases but the thermal efficiency increases and energy consumption is reduced. The extent of this benefit depends on the flight profile of the aircraft and the related fraction of fuel used under lean conditions. Techniques have been developed for gasoline-fueled operation that partially offset the penalty from rich fuel mixture control. Comparison of results with methanol and avgas could be made by use of a computer program simulation, which may be available, but this has not been done to our knowledge.

There are some factors related to this subject that must be considered in any evaluation. First, it is extremely difficult to obtain meaningful comparisons of two fuels (or any other item) due to differences in equipment, operator response, operational schedule, climatic conditions, and the like. To achieve statistical significance, a very large sample size is required. With automobiles, operational data are required over about a year with a minimum of 25 carefully controlled vehicle pairs (one test, one reference) to achieve results that are statistically significant to the 90 to 95 percent confidence level. Engine test stand results are far easier to obtain, but this still requires comparison of best performance on the reference fuel (say gasoline) to best performance on the substitute.

Another factor relates to the relative heat of vaporization of the fuels involved. On a unit energy basis, it takes about seven times as much heat to vaporize methanol as it does gasoline (four times as much for ethanol). Also, since methanol combustion is cooler and aircraft engines use exhaust heat to condition the intake air and fuel charge, less heat is available for cabin heating when methanol is used. There is little relationship between this effect and engine efficiency.

Pilots have observed that alcohol fuels give better operation at high altitude than gasoline, but this has been erroneously attributed to the oxygen contained in the fuel. The oxygen content of the fuel equates to partial combustion, so in essence methanol is half combusted which is why the energy per unit volume is half that of gasoline. Differences in engine operation at high altitudes with a change in fuel undoubtedly relate to accompanying changes in engine configuration and/or adjustment.

Gaseous fuels such as methane and hydrogen have been assessed to a substantial extent under NASA sponsorship. These fuels need to be liquefied in order to achieve storage characteristics suitable for consideration, and a substantial energy penalty is paid for this transition. Studies made for the NASA Langley Research Center several years ago show that, using technology that could be operational in the 1990s, both liquid methane and liquid hydrogen could provide benefits over petroleum fuel (Jet A) in a subsonic commercial aircraft under some circumstances. At ranges less than 1500 nautical miles (n.mi.), neither are competitive with Jet A fuel. For ranges of 1500 to 5500 n.mi., liquid methane is competitive with liquid hydrogen and both are superior to petroleum fuel. At longer ranges, liquid hydrogen is superior to both liquid methane and Jet A, primarily due to greater gravimetric energy density and the resultant lighter weight of the fuel and redesigned aircraft. These assessments involved detailed analysis of design factors unique to each fuel, generally denoting technical feasibility. Studies have also addressed potential safety problems.

It has been the DOE experience in alternative fuels use that a few basic factors are key to industry participation and eventual involvement. First, availability of valid and basic data is necessary to put things in context. Second, technology transfer needs to start at the outset of work and go on continuously thereafter. Accordingly, the AFUP has fostered the flow and exchange of information to and among industry experts who have found this service to be a most valuable tool for their activity. However, an essential ingredient of peer meetings is that substantive new information be available. Since the DOE does not carry a lead role in this area it does not appear practicable for it to act as a major stimuli.

In summary, the SFC plays the lead Federal role in encouraging production of non-petroleum fuels. DOE has, prior to SFC activity, contributed appreciably to promoting use of available technology to convert non-petroleum resources into transport fuels. DOE has been and continues to be active in researching new technologies for conversion of oil shale, coal and biomass into useful forms for transportation as well as other applications.

DOE's end use activities emphasize appropriate basic data for fuel/engine couples that permits industry experts to establish designs suitable for commercial applications. There are a limited number of engine types, and those used in aircraft are also being used or researched for automotive applications. Fuel-related information is generally pertinent to both. Therefore, information basic to the use of alcohol fuels and methane in automotive reciprocating engines is pertinent to and available for use with this type of aircraft engine. A similar data base on use of gasoline-like synthetic fuels has been started. Use of methane in stationary gas turbine engines is similarly applicable to both automotive and aircraft turbine engines. Aircraft manufacturers will presumably use available technical information to address those options which provide the most favorable potential for widespread application, while niche applications may be pursued by those who perceive unique business opportunities to warrant the necessary investment.

The DOE role in the use of new aircraft fuels is of a cooperative nature with NASA and DOD with a view toward providing related basic technical information from work in the highway transport sector. DOE will, through the AFUP, continue to encourage progress among researchers and within industry toward pertinent solutions to the use of appropriate alternative fuels to replace petroleum in aviation.

Mr. GLICKMAN. Thank you, Mr. Hall. We appreciate the fact that you did summarize. One of the things that concerns me is the eventuality of a disruption of world crude oil supplies, crude oil, and gas supplies, and I'm wondering, just in the generic sense, does the administration have any plans with respect to a future intense disruption of world crude oil supplies?

Mr. HALL. Mr. Chairman, I feel like what the administration is trying to do is to have an energy policy that makes sense. That is, one where we have an adequate supply of energy at reasonable prices, and adequate options for—for people, for you and I to make our decisions upon. I think that's what we have been about in the research for alternative fuels to provide the information, make it available so that in the event that these disruptions occur, we have some options to go to, and further, even if they don't occur, that people have the information available to make economic decisions regarding their use.

Mr. GLICKMAN. I guess my concern is that, you know, we can rely on the marketplace and we can continue to do the necessary research work which is what, one of the things the Government has a continuing role in, but in 1973 during the crude oil embargo, I think it's a general feeling, or the fairly well acknowledged feeling in aviation that general aviation was left out in the cold at that time period and had a dramatic effect on the ability of people to buy airplanes. And I'm just kind of curious what contingency plans do you have in the event of another major world disruption of crude oil.

Mr. HALL. I guess my feeling is, Mr. Chairman, that since that happened in 1973, that the research has contributed significantly to making information available. I do feel that now that research has been done in larger measure, it's continuing to be done, there is a lot of refinement that is necessary, but a lot of research is there, a lot of information is there, and should these eventualities occur, I believe that we do have options available. Again, though, that will be decided by industry when that time comes.

Mr. GLICKMAN. I guess if tomorrow the Saudis and the Iranians and Kuwait or whomever else decided not to sell us any more oil, we might be a little better off than we were 5 or 6 years ago, but you probably couldn't see any immediate substitution, broad-scale substitution to alternative fuel. And in that case, general aviation, commercial aviation, and all sectors of the economy would suffer rather dramatically, I guess. My point is, while by supply and demand we are in better shape now, we still aren't much improved over where we were 10 or 15 years ago in order to get that kind of immediate substitution capability into alternative fuels. So, my—I guess my point to you is that I would hope that you, not only alone but in coordination with NASA and the Pentagon and whomever else is doing this kind of work, sees a need for research programs to search for substitute fuels generally and substitute aviation fuels specifically.

Mr. HALL. All right, sir. Thank you, and I'll convey that to Secretary Hodel.

Mr. GLICKMAN. Mr. Carney?

Mr. CARNEY. Thank you, Dan. You said that there are programs, Mr. Hall, that are currently being investigated, there are four substitute fuels. Could you identify some of them that would be directly involved with the aviation industry that are being conducted by DOE?

Mr. HALL. I'd like to have Mr. Eckland respond to that.

Mr. ECKLAND. We have long worked in the area of alcohol fuels for spark ignition engines, almost 10 years now. There is a very well established data base in this particular area. There are still some remaining problems that Mr. Hall mentioned before, but for the most part the information is sufficient for industry to move ahead with it. The fundamentals apply with it, whether it be to a piston aircraft engine, light aircraft, or to your automobile engine.

As you probably know, in the automotive side, people, manufacturers like Volkswagen and, more importantly, Ford Motor Co., have gone through a couple of experimental design changes just a short time ago. Ford Motor Co. produced some 587 automobiles on the production line for use in California to operate on straight methanol. The technology is there. There are some remaining problems and we have been working on them. Part of this is a matter of wear. There is abnormal wear in a methanol-fueled engine compared to that of gasoline engines. A great deal of progress has been made. Doesn't stand in the way of its use at this stage in the game, but we don't know for sure the reason for this. There are two different theories that have been exposed by the contractors to use. They are both different and yet they may be mutually involved in the situation, and both of those are being pursued, while industry in the meantime proceeds with the matter of formulating special lubricants that cut down the wear very substantially.

Similarly, cold starting and warmup is a problem, but because it takes a great deal more heat to vaporize alcohol fuels, and as a result, why, that heat is not available with a cold engine. The typical way that is being used today is to add some light gasoline components in to help it start, just as it is done with petroleum products, but we have been working for about 5 years, looking at the different methods to be able to mechanically enhance the cold starting techniques. So those activities go on.

We are also doing work in natural gas, we have a project that's about halfway through right now that builds the data base for the optimum use of methane, the information that would benefit the engine designer, if the designer went out to specifically design the engine for methane rather than for gasoline, and that's about halfway through, as I say.

There is going to be, looking at two different combustion chambered configurations in that those are both spark ignitions of the type used in aircraft and automotive work. The work on one combustion chamber configuration will be done in 2 or 3 months, and the other early next calendar year.

Mr. **Carney**. Are those programs, if I'm correct, are independently conducted programs in the private sector sponsored by DOE?

Mr. **Eckland**. Yes, sir.

Mr. **Carney**. Mr. Hall, would you know what type of money DOE is spending in fiscal year 1983 for these types of programs?

Mr. **Hall**. In fiscal 1983 we had $1½ million in the budget. In the President's budget for fiscal 1984 there is $4 million.

Mr. **Carney**. And my final question, Mr. Hall, do we have the capacity as a nation, if we make the breakthroughs—I'll have to set up this hypothetical situation if I may—we make the breakthroughs necessary to get around the problems of cold starting, get around the problems associated with alternate fuels like methanol or methane or ethanol, do we have the basic raw materials to produce the types of quantities necessary to provide the fuel that would be consumed in the future?

Mr. **Hall**. Yes, we do.

Mr. **Carney**. And would we have the manufacturing process—I know we don't have it right now—but do we have the technology to put into place the manufacturing processes necessary to refine these types of fuels to a state where they would be usable?

Mr. **Eckland**. Yes.

Mr. **Hall**. Yes, sir, we do.

Mr. **Carney**. Thank you very much. That's all the questions, Mr. Chairman.

Mr. **Glickman**. I want to thank you very much for coming here. I want to reiterate the fact that I recognize a lot of the work is being done by NASA, and of course your department has the responsibility for managing, at least from a Federal perspective, energy problems generally. And not only is some of the base research work being done for the Department of Energy because it parallels the automotive work, but I know Mr. Eckland has been involved with it in the past, that you'll have the responsibility for managing those problems which exist on shortages, the kind of problems we went through in the 1970's that hurt the aviation industry so badly. I know we have some aviation gasoline shortages still existing in certain parts of this country, and so I think that it is highly important that you work aggressively within the limits of reasonable budget picture to try to ensure that there is some long-term future for the availability of aviation fuel, which of course the production of airplanes is one of—is one of this country's winners, and I hope the Government recognizes that as it continues its research and conservation work.

Mr. **Hall**. Thank you, Mr. Chairman, and I appreciate those words. And we are, as you said in the beginning, we share your concern. We are working hard to try to determine what the legitimate and valid role for the Federal Government is in making these things a reality. And we continue to appreciate any help and guidance that you have.

Mr. **Glickman**. I just would say that pinpointing the necessity for the private sector to move ahead in this area, which I agree should be the fundamental place. I assume that you are noting the relationship between the private sector and Governments in the rest of the world and that, how important it is for U.S. industry to remain competitive in light of the Government subsidization in the rest of the world. And I'm not arguing for that here, but I am arguing for an activist, cooperative relationship, and the aviation industry has been, again, one of those unique areas that there has been, not the history of bitter fighting between Government and industry like we have seen between so many other industries.

I believe Mr. Carney had a closing comment.

Mr. **Carney**. I would like to say, Mr. Chairman, if these gentlemen will take the opportunity to view the static displays that we have here in Wichita of some of the aircraft that have been fitted out for alternate fuels, it might be worth your while.

Mr. **Hall**. Yes, sir, I intend to do that.

Mr. **Glickman**. Thank you both for coming here today.

Now, the next witness panel is one private sector panel on the question of immediate alternatives to petroleum, and we have Roy Adkins, director of programs, Alternative Energy Department here at Beech, and we have Harry Zeisloft, chief engineer for Research, Experimental Aircraft Association, in Wisconsin. It's a pleasure to have you both here. I think one of you—don't you have a visual display?

STATEMENTS OF ROY ADKINS, DIRECTOR OF PROGRAMS, ALTERNATIVE ENERGY DIVISION, BEECH AIRCRAFT CORP., WICHITA, KANS., ACCOMPANIED BY HARRY MAGRI, FLIGHT TEST PILOT; AND HARRY ZIESLOFT, CHIEF ENGINEER FOR RESEARCH, EXPERIMENTAL AIRCRAFT ASSOCIATION, HALES CORNERS, WIS.

Mr. **Adkins**. I'm accompanied this morning by Mr. Larry Magri, who is our flight test pilot on the Sundowner program.

Mr. **Glickman**. Fine.

Mr. **Adkins**. On behalf of Beech Aircraft, I would like to express our appreciation for having this opportunity to make our statement to this committee this morning.

The company has been actually involved in alternative fuels for aviation since the late 1950's. Our studies at Boulder, Colo., on our programs like the Dinosaur project, using liquid hydrogen, and later on made contributions to the supersonic transport program for NASA, wherein liquefied methane was one of the fuels that was recommended as a fuel for that aircraft. More recently, our work since the early 1960's has been devoted to manned spacecraft programs, and the design and production of the cryogenic oxygens and oxygens in liquefied helium systems for those.

And what I'd like to do at this time is go directly into a brief slide presentation and summarize the company's work on that.

Mr. **Glickman**. Sure.

Mr. **Adkins**. As I said, our background and experience spans back 25 years, actually in the manned space program. One of the first programs that we were successful on as the Gemini project. The areas of interest to Beech Aircraft were the airborne tanks on the Gemini and the controls for transporting and conditioning the cryogens onboard the spacecraft, and the transport equipment at the base of the gantry to transport the oxygens and the hydrogen to launch site. This led to the successful acquisition of the Apollo program, and the company designed and produced approximately 42 ship-sets of liquid hydrogen and oxygen tanks for the *Apollo* spacecraft. This is how the systems, liquid oxygen and hydrogen, in the service module looked atop the complete Saturn launch vehicle. We are currently designing and producing the same systems, liquid oxygen and liquid hydrogen, for the shuttle transportation system. In addition, we have a total of two oxygen and two hydrogen systems. This will increase to nine oxygen, nine hydrogen, for the extended missions, in all cases.

Beech Aircraft's area of interests are in, again, the airborne tanks, the vehicular tanks themselves, and the associated ground supporting equipment and fueling equipment that is used to fuel. This transition in technology to the transportation sector took place in 1971. As a result of programs that were sponsored by the General Services Administration and the Department of Transportation, and a position paper that was issued by the EPA for the use of gaseous fuels as a vehicular fuel to improve air quality in this country, Beech Aircraft saw an opportunity in this country. Beech Aircraft saw an opportunity to make a contribution with the manned spacecraft technology.

One of the points that we would like to call attention to is that the hardware is capable of being used with either liquid methane or liquid hydrogen. In 1973, the Ford Torino on the right was equipped with a liquid methane system, and the 1973 Monte Carlo on the left was operated on liquid hydrogen. One of the things that we need to clarify, I guess, or consider, are the various fuels that can be considered alternative fuels. Hydrogen, although it was an early on favorite, the cost is prohibitive at the present time. And one of the things that you have to consider, that even though the technology is there, the hard facts for today are the availability, the supply, the economics, the environmental considerations, and which stands the best chance in the marketplace from an economic standpoint. Methane, at 1,170° hot surface ignition temperaure, is one of the reasons that we feel qualifies it as one of the safest fuels that's available today, and we'll discuss that more as we get into the Army aviation program.

These prices were as of January 1982, and as you can see, economics is the driver of the system that we are talking about today, while back in the early 1970's, clean air is the driver. In 1971, at the end of 1971, this country was spending around 1 percent of our gross national product on energy. At the end of 1981, this had risen to over 12 percent. Needless to say, that drain on the consumer purchasing power has had its impact, not only in the aviation industry, but in the automotive industry, agricultural and other industries.

One of the reasons that we have plotted this in this manner is to give you some idea. There is a distinct relationship between the number of vehicles, for example, that were produced in this country, from a high of 12,800,000 back in 1977 to this year, currently under 7 million. The same impact has been felt in the aviation industry.

Also, it's interesting to note that OPEC's production has been trimmed back to maintain those costs, and whether this oil glut will last for 3 months or 3 years, it's going to be with us from here on out. We are undergoing a fundamental change in the supply and availability of fuels. This is one of the reasons that, again, that Beech Aircraft is undertaking the type of program that we have been involved in for the last 11 years.

The Alternative Energy Division was formally established in August 1980. The charter at that time was to design and produce and market conversion systems for automotive fleet use, primarily automotive fleets. That's what we are doing at this time. The core of the system is nothing more than an elaborate Thermos bottle that you might keep your coffee warm in. This particular unit, though, you would put your coffee in this Thermos bottle and it would still be hot probably 10 years from now. It's that type of thermal efficiency that we are talking about. It's a vapor feed system. This is a schematic of how it works.

In addition to the automotive systems, we are also currently marketing diesel conversions. The underhood components have just recently become available in this country. The diesel conversion works essentially the same way. It's a vapor feed tank, and the fuel is metered and injected directly into your air chamber, and you go through your normal compression and ignition cycle. One of the interesting things that happens in diesels, we do pick up sufficient horsepower, as noted in that last slide, the horsepower off that Cummings went from 210 to 230 horsepower. The system uses a combination 17 percent diesel fuel and 83 percent methane, and you use the conversion factor of about 1.3 gallons of liquefied methane will back out 1 gallon of diesel fluid.

One of the earliest stations that we opened in November 1982 was at Northwest Natural Gas. Our programs are equally divided between conventional and unconventional liquefied natural gas systems. This one utilizes conventional utility-type gas, fueling operations fairly simple and straightforward. The transportation of fuel between the liquefaction plant and the filling station is by over-the-road tankers. This is the large size of around 10,000 gallons, with a net of around 10,600, and they go down as low as 300 gallons. The system elements for a conventional methane system consists of fueling station, it's the bulk storage facility, and the condenser and the conversion kits. With the advent of the onsite transportable-type liquefaction plants, we are now able to go into coal seam gas operations and sewage plants. There are over 16,000 of these in the United States producing something like 60 billion cubic feet of natural gas a year, which by and large is being expended as waste and burned, flared I mean, to the atmosphere. And also the landfill gas that's available to practically every major municipal service organization in the United States, around 55 billion cubic feet of natural gas a year being produced in landfills, which is by and large unutilized at this time.

Biomass, right here in Wichita, we have a feedlot operation and a slaughterhouse operation around—that's slaughtering around 5,000 head of cattle per day. By and large the biomass from those facilities are unused at this time.

We are finding a lot of response in these areas for this type of gas utilization, and last but not least, of the landlocked wells which cannot be hooked into the existing as line system in this country. For those systems we are talking about, the complete liquefaction, transportation, for the fueling system, the dispenser and the conversion kits, and these areas, Beech Aircraft have teamed with the other contractors, Beech Aircraft pilots and services for these systems, and amounts to about 30 percent of the program, and the other systems amount to the remaining 70 percent.

In the unconventional systems, for a fleet of around 300 vehicles—and I might point out at this time that as a minimum, we do not attempt to convert any fleet under 150 vehicles, so we are talking about fleet operations between 150 to 300 in a system, that I have outlined for fleets in those sizes, and a total cost for those systems is around $3.3 million, and the payback time runs just a little under 3½ years. Fleet-operated vehicle uses approximately 2,100 gallons of fuel per year. Some of them get, like Purolator Corp. has as high as 5,000 gallons, and an over-the-road transport, 18 wheeler, uses around 18,000 gallons of diesel fluid, so all of these systems have a much improved payback time based on the amount of fuel that they actually use.

In addition to the automotive program, we are using a similar approach in the aviation industry, going after those fleet-operated aircraft that lend themselves to this type of a systems approach. Sundowner Aircraft was the first aircraft to fly on liquefied methane in August 1981. Since that time we have accumulated, I believe, a little over 50 hours of actual flight test time. The end market here would be in the flying cool environment similar to an Embry-Riddle, where you are able to remove the aft two seats and replace those with the fuel system. And it is a conversion approach that we are using. You still have your pilot and your instructor in the left side, and your student in the right-hand seat.

One of the things that we are able to do is use a pretty straightforward approach for the conversion with the addition of the fuel-air mixture. The heat exchanger, vaporizer, the fuel tanks, as I have covered before, and the fueling is with the same equipment that's used for automotive application.

One of the things that I'd like to point out here, that we do have about a 9-percent decrease in shaft horsepower, and this affects the time to climb to altitude. It does affect the takeoff distance, which Mr. Magry will answer any questions in that area, but most importantly to Beech Aircraft and to the young students that's learning to fly is that the per hour fuel costs go from $21.32 an hour to $6.76 an hour, and that's using a cost, I believe, of 65 cents a gallon for the liquefied methane, and it's based on a 600-hour-a-year flying school environment, and on a per day basis of around 2.29 hours per day. The difference then operating that aircraft is $48.81 to $21.47. The annual fuel cost saving per aircraft in an Embry-Riddle Flying School type environment would be around a little over $8,000. Conversion cost is estimated at this time around $15,000, the payback time is 1.7 years. There are around, between 10,000 and 12,000 fleet-operated aircraft that we have identified in our marketing and research that are excellent candidates to use liquefied methane.

We are currently under contract to the U.S. Army in their helicopter flight training school at Fort Rucker to convert the TH-55 helicopter to run on liquefied methane. Phase I consisted of the systems design, which was accomplished at our Boulder, Colo., facility. Phase II of it is engine test stand runs and the airworthiness certification of the PO system component, and phase III is the flight test phase, which we are into right now. They are running the av-gas baseline tests. I think they are just about finished at Fort Rucker now, and the first week in September we'll be converting the instrumental aircraft over to operate on liquefied methane. And during September and October we'll be conducting our actual flight tests. We'll duplicate the Army's basic training sortie with all the appropriate maneuvers the same as we have done for the av-gas.

Again, one of the—I might add that the Air Force has done all the testing and certification of the components for the Army at their test facility at Eglin Air Force Base. The Army's primary interest, again, was one of economics. They operate that aircraft around 786 hours a year, 3 hours a day, and their per day operating costs go from $62.40 to $18.77. The Army purchased their liquefied methane under a competitive contract from a local gas company for 42 cents a gallon, and that's a 3-year contract.

I might add also that we have just received a purchase order from the Army to convert Army ground vehicles at Fort Rucker. The two programs are not associated with one another but they'll use identical fueling facilities. The savings per aircraft to the Army is over $11,000 per year, and with 144 aircraft, their annual savings for the entire fleet will be over a $1½ million. The Army's plan is, if it's successful, to either put that back into additional training time or into improved aircraft, or just savings that would be applied to their training school operations there at Fort Rucker.

Some of the other areas that we are looking at right now and people that we are working with are the folks like Petroleum Helicopter, Inc., which operate over 400 rotary-wing aircraft in fueling operations over the Gulf of Mexico. One thing that makes it nice is they have about 30 percent of the market share and they have gas that is being flared at these places, and we have been discussing doing onsite liquefaction at the platform on a barge-mounted liquefaction unit. Right now they have to maintain around 5,000 gallons of fuel at each one of the facilities. Using liquefied methane on their helicopters would give them an opportunity to do away with logistics problems and reduce their fuel cost tremendously, since the flare costs, feed stop cost would be essentially zero. What it means is that their Bell 206B, which they have asked us to take a look at, annual fuel cost savings are on the order of $30,000 per aircraft Those aircraft are operated on the average of around 100 hours per month.

And there are many aircraft, by the way, that fall into this category in the industry sector. Additionally, in the military, there are now aircraft, rotary-wing aircraft being qualified with experimental source systems. In a turbine-powered aircraft you also use—our plans would be to always use the liquefied methane as a complement to a fuel rather than the main fuel; you can switch back and forth from one fuel to the other. GE has satisfactorily demonstrated that in study programs that they accomplished for NASA back in the late 1960's.

Another type of helicopter is the Navy Sikorsky CH53. Again, with the dispenser stores there, the fuel tanks would be fitted into place, those experimental stores, and for all the training exercises and the training hours that you put in, you would merely substitute the liquefied methane tanks for the jet A tanks.

Some of the early work by Pratt & Whitney on turbine engines indicated time between overhaul, for example, would be from 3,000 to 12,000 hours. This was based on over 450,000 hours of engine test time on the ground unit. These are the same units that are used for pipeline transmission system. It's also, of course, the PT6A-20 engine, which Beech Aircraft uses a significant number of.

Some of the nice things that can be done with liquefied methane as aviation fuel is using the heat sink of the methane to cool the bleed air, and the bleed air is in turn fed back into the hot metal sections of the engine, which allows you to maintain a much lower hot metal temperature, which is the primary reason for the erosion of the metal parts. But in addition, the inlet combustion temperature can be increased from 1,600° to over 2,500° with a resultant increase of approximately 20 percent shaft horsepower to the aircraft, just by charging the fuel in the aircraft.

In piston-powered aircraft, we go from about, I think 25° before top dead center, to around 35° before top dead center. Other than that, there are no changes made to the engine whatsoever.

That concludes my portion of it.

[The prepared statement of Mr. Adkins follows:]

Statement of

ROY E. ADKINS

Director of Marketing
Alternative Energy Division

BEECH AIRCRAFT CORPORATION

ROY E. ADKINS

Roy E. Adkins, Director-Marketing, Alternative Energy Division

Responsible for the development of marketing plans, engineering support and product service for all Beech alternative energy programs. Additional responsibilities include the negotiation of joint ventures and license agreements associated with the marketing of methane technology and products.

Mr. Adkin's 27-year career in engineering and marketing at Beech includes 10 years of research and development in aerospace cryogenics systems, and alternative transportation fuels for aviation, automotive, marine, and industrial vehicles.

During his assignment as Manager—Marketing, Advanced Systems, he coordinated Beech activities on the Gemini, Apollo, Skylab, and Space Shuttle projects.

At the company's Boulder Division he managed the environmental test facility in testing liquid oxygen and liquid hydrogen propulsion system components for the Atlas, Titan, and Centaur Missiles.

Adkins joined Beech in 1956 in Wichita as a design engineer for electrical systems on missile targets. Previously, he served as a design engineer for Lear Aircraft and Hughes Aerospace. He studied mechanical engineering at Washington University, St. Louis. He and his family reside in Catlett, Virginia.

INTRODUCTION

Beech Aircraft's interest in Alternative Fuels has evolved as a result of corporate management's long term commitment to meeting man's transportation needs. Acknowledged as a leader in the aviation transportation industry for over fifty (50) years, the public and industry perception of Beech Aircraft is usually limited to our aircraft products and services. However, the company has also been involved in alternative aviation fuels research, primarily liquid hydrogen and methane, and aerospace cryogenics for over twenty-five (25) years.

Early research contracts involved a tankage and fuel system study for the U.S. Air Force in 1956 on the "Dynasoar" project. Ten years later, the company contributed to NASA studies on the methane fueled supersonic transport aircraft (SST).

In addition to these research activities, major achievements by Beech in this country's space program included the liquid oxygen and hydrogen conditioning and fueling system for the Gemini spacecraft, the liquid helium (−452°F) system for the lunar landing module and the airborne oxygen and hydrogen tanks for the Apollo project. The company is currently producing both the airborne cryogenic tanks and the associated ground support equipment (G.S.E.) for the space shuttle orbiter, this country's first reusable space transportation system.

The use of liquefied methane in federal automotive fleets by the General Services Administration (G.S.A.) in 1972 generated a great deal of interest in the aerospace cryogenic industry. It was during this period that Beech engineers designed and produced the company's first automotive fuel conversion systems. The equipment was capable of operating on either liquid hydrogen or methane and both fuels were successfully demonstrated in early 1973. Gasoline was 28¢/gallon and av-gas was about 35¢/gallon. By comparison a gallon of "LNG" could be purchased at that time for about 16¢/gallon. Gasoline lines were still to come and in the early 70's, the driver behind this new automotive fuel concept was an improvement in air quality, since overall emissions could be reduced by approximately 90% through the use of methane.

It was not until the dramatic run-up in fuel costs in 1979-1980 period that economics became a significant factor in the search for alternatives to petroleum-based fuels. The potential resources for hydrogen production from sea water and coal made this candidate fuel an early-on favorite. However, advancements in technology must be coupled with hard economic factors in determining which form of alternative energy, fusion, solar, methanol, shale, synthetics, electric, hydrogen, or methane will emerge as the "fuel of the future." During the past fifteen (15) years, there have been a number of studies and test programs sponsored by the federal government and industry to evaluate the use of liquified methane in automotive, aviation, marine, and surface mass transit systems. The concensus appears to be that with respect to the critical questions regarding supply, environment, safety, economics, and operational suitability in existing power plants, methane is a superior first choice for immediate utilization. The following table provides a comparison of the basic characteristics of several fuels and their average price as of July 1, 1983.

TABLE I.
ALTERNATIVE FUELS COMPARISON

	Lbs. per Gallon	BTU Per Gallon	BTU Per Pound	Hot Surface Ignition Temperature	Octane	Density Pounds Per FT³	Price Nat. Avg. Jan 82
METHANE	3.53	83,700	21,500	1170°F	130	26.5	.55
METHANOL	6.60	57,000	8,600	660°F	110	65.0	.81
PROPANE	4.86	91,500	19,700	750°F	110	36.5	.83
HYDROGEN	0.6	30,000	51,600	800°F	120	4.3	4.00
GASOLINE	6.8	120,000	19,000	680°F	89	50.0	1.24
AV-GAS	6.2	125,000	19,000	500°F	110	50.5	2.05
JET A	6.5	125,000	18,600	500°F	40	50.5	1.65

As the table shows, methane is obviously a high performance fuel and cheaper than either AvGas or JP.

What is Methane?

Since methane is often confused with other fuels, such as propane, butane or methanol, perhaps a brief resume of this fuel is in order. Methane gas is the primary constitutent of natural gas. The expression "Natural Gas" is merely the term used to identify a family of gases that are usually found together in various combinations and mixtures. Methane is also a renewable resource and can be produced from coal seams, animal wastes, sewage plants, landfills, and biomass. Therefore, the exact chemical composition of a particular natural gas depends on its source and geographic location.

Methane Supply

Leading industry and government sources are in agreement that proven reserves of natural gas are greater than the reserves of oil in the United States. Shortages and disruptions of natural gas supplies have been the result of deficiencies in the domestic gas distribution system and in government regulations rather than in a shortage of the commodity itself. Conventional US domestic reserves of natural gas are estimated at 208 trillion cubic feet (TCF) with an annual use rate of approximately 18 TCF.

The average conservative estimate of unconventional and uneconomical natural gas or methane is approximately 10,000 TCF, or enough to last over 500 years at our present use rate. Table II summarizes the supply picture of unconventional natural gas based on the estimates of five prominent authorities.

TABLE II
ESTIMATES OF TOTAL U.S. RESOURCE OF UNCONVENTIONAL NATURAL GAS (TCF)

Resource	**Range of Resource Estimates**				
	GRI[1] Assessment	**NEP-11[2]**	**FERC[3] 6/78**	**ERDA[4] MOPPS**	**DOE[5] ET-VI**
Western Tight Sands	50-600	50-420	793	600	50-320
Eastern Devonian Shale	75-700	25-400	285	600	10-520
Methane From Coal Seam	72-860	50-700	850	2500	16-500
Geopressured Zone Methane	3000-5000	5000-63000	n/a	3000	150-200

Sources for the preceeding table:

1. Gas Research Institute, Gas Research Institute Digest, Vol. 2, No. @ March 1979.
2. Department of Energy, National Energy Plan-II, May 1979.
3. Federal Energy Regulatory Commission, Nonconventional Natural Gas Resources Report DOE/FERC-D010, June 1978.
4. Energy Research and Development Administration, Market Oriented Program, Planning Study (MOPPS) Review Draft, June 1, 1977.
5. Energy Technology VI, Gas Recovery from Unconventional Sources by DOE/Morgantown Energy Technology Center, February 26-27, 1978.

Environment

The use of methane as an air and ground transportation fuel achieves positive improvement in all areas of environmental concern: land, water, air quality and socio-economic effects. These improvements apply throughout the "methane energy grid" including production, transmission, storage, distribution and end-use. In an extensive test program conducted in 1972 by the General Services Administration in controlled fleet operations, overall emissions were reduced by 89%. In more recent tests conducted on a 1980 Pontiac Phoenix in Denver, Colorado by an E.P.A. Qualified Test Facility, the following high altitude results of the Hot E.P.A. 75 CVS Emissions Test were achieved:

	HC	CO	NOX
E.P.A. 1980 Clean Air Standard	.41 Grams per mile	7.0 Grams per mile	2.0 Grams per mile
1980 Pontiac Phoenix	.13 Grams per mile	1.6 Grams per mile	1.9 Grams per mile

Economics

Undoubtedly the most compelling argument for the use of methane in the air and surface transportation sector is lower cost and domestic availability. With the advent of the small scale, transportable, on-site liquefaction units and the availability of safe, reliable, cost effective liquefied methane fuel systems, including stations, dispensers and vehicular tanks, fleet operations are already achieving a 40% to 60% reduction in annual fuel costs, with a total system payback of approximately three (3) years. In addition to fuel cost savings, fleet operators have experienced a 40% reduction in routine maintenance (spark plugs and oil changes) and engine life is doubled.

According to the D.O.E.'s Energy Information Administration (E.I.A.), natural gas, even with decontrol, will continue to enjoy a cost advantage over petroleum products. In its report to the Congress and to the Department of Defense in March, 1981, the E.I.A. presented a mid-case scenario, which projected an increase in oil prices based on a 9% to 12% inflation factor with no disruption of O.P.E.C. oil supplies. Realistically, it should be pointed out that U.S. intelligence sources including the Central Intelligence Agency (CIA) and the Defense Intelligence Agency (DIA) predict at least three major disruptions every ten years in Mid-East oil supplies. The current "oil glut" is a result of price increases since the 1979-1980 disruption, and a reduction in world-wide consumption of over 10% in the last two years. The old law of supply and demand is presently at work in reducing oil use.

However, despite this reduction in demand, energy costs in the United States for 1981 absorbed 12% of the GNP, up from less than 1% in 1971. The impact on the American automotive, aviation, and agriculture industry has been substantial. Figure 1 illustrates the impact of oil prices on both automotive sales and O.P.E.C. production.

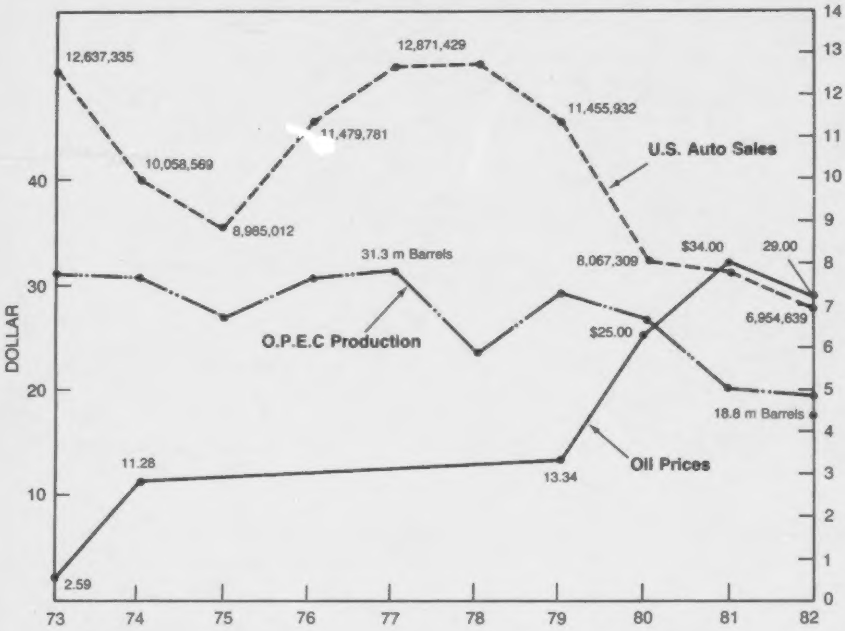


FIGURE I.
IMPACT OF OIL PRICES ON AUTOMOTIVE SALES AND O.P.E.C. PRODUCTION

As a result, the American consumer's purchasing power and investment dollars are being drained off by the high cost of O.P.E.C. oil. Instability of oil supplies and prices will continue to influence world political and economic relationships, and whether it lasts three months or three years, the so-called "oil glut" is only a predictable market correction and not a change in the fundamental problem of diminishing petroleum supplies.

In August of 1980, Beech Aircraft Corporation formally entered the energy field with the establishment of the Alternative Energy Division. The broad charter of this organization was to design, produce and market cryogenic fuel systems using liquefied methane or hydrogen as a fuel for automotive, aviation, marine, and surface transportation systems. Initial marketing efforts to date have been concentrated on fleet operations. There are approximately 15 million fleet operated motor vehicles in the United States out of a total vehicle population of about 142 million. Every million vehicles converted to methane can reduce oil imports by 296,000 barrels a day.

Safety

There are several characteristics of methane that make it an inherently safer vehicular transportation fuel than petroleum-based fuels. Methane is non-toxic, non-corrosive, lighter than air and has a hot surface ignition temperature that is over 600°F higher than gasoline. As a result of studies and actual crash tests conducted in the early 1970's, the Department of Transportation, the General Services Administration and the Environmental Protection Agency concluded that "liquefied methane" is as safe as petroleum based fuels for automotive use. In addition, NASA studies have confirmed the safety features of liquefied methane as an aviation fuel. The U.S. Coast Guard, which grades the relative hazards of materials that pass through US ports, ranks Liquefied Natural Gas (LNG) a very low nineteenth out of twenty-two commodities under Coast Guard Jurisdiction. The following table graphically compares the fatality probability of LNG operations with known risks.

TABLE III
COMPARISON OF LNG OPERATIONS RISK ASSESSMENT WITH KNOWN RISKS

Accident Type	**Fatality Probability Per Exposed Person Per Year**
Motor Vehicles	1 in 27,000
Falls in Public Places	1 in 240,000
Fires in Homes	1 in 260,000
Falls in Homes	1 in 460,000
Fires in Public Places	1 in 3,000,000
Air Transport	1 in 5,000,000
Poisoning by Gases	1 in 5,000,000
LNG Operations	1 in 10,000,000 to 1 in 100,000,000
Lightning	1 in 50,000,000

Sources:

1. Supply of Liquefied Natural Gas to the Northeast (Upton, NY, National Center for Analysis of Energy Systems, Brookhaven National Laboratory for U.S. Energy Research and Development Administration, April, 1976) p.68.
2. Accidents and Unscheduled Events Associated with Non-nuclear Energy Resources and Technology. (Washington, D.C., U.S. Environmental Protection Agency, Feb. 1977) p. 174. Figures shown for LNG were derived from assessments performed by Science Applications, Inc. and El Paso Alaska Co. Range reflects different sites and methodologies.

Methane: An Aviation Fuel

Following WWII, there was a dramatic revolution in aircraft engines. In less than ten years, gas turbine engines replaced reciprocating engines in both commercial and military aircraft, and aviation gasoline gave way to JP fuels. Today's modern aircraft and jet engines feature technologies that are relatively mature. The engines operate at primary combustor efficiencies of 98% and at turbine efficiencies on the order of 90%, with gas temperatures close to the melting point of the engine hot section metals. For aircraft performance and operting costs to show a significant improvement in the future, fundamental changes will be required. Such a change occured in the transition from pistons to jets. A comparable step improvement is now possible with the use of liquefied methane as an aviation fuel.

In the aviation sector there are approximately 10,000-12,000 aircraft including *military, agriculture, mining, petroleum, flying schools* and *commuter airline* operations that are excellent candidates for utilizing liquefied methane as a complimentary fuel in auxiliary fuel tanks.

These aircraft are essentially operated in a "fleet environment" where fueling, maintenance and day to day flight activities are accomplished in accordance with a set schedule of events. In turbine powered aircraft the liquefied methane may be installed in a dual-fuel mode where the methane is used as a complimentary fuel with the aircraft retaining its full JP fuel capability. A typical turbine engine conversion system would include dual fuel injectors, methane fuel controls, heat exchanger, cryogenic fuel pump and external wing or fuselage mounted methane fuel tanks. The wing mounted tanks could be installed on existing "external stores" attach points with a minimum amount of modification to the aircraft. The dual-fuel JP/Methane system would be utilized primarily in training and flight proficiency activities and is not intended to be used in an operational scenario or combat situation. With commercially available LNG cost at approximately .55¢ per gallon, the annual fuel cost savings would be substantial. Consider the potential savings for CH-53 HLH and the UH-60A rotary wing aircraft shown below.

Total Fleet Size Aircraft
Navy — Sikorsky CH-53 HLH
Marines — Sikorsky MH-53
External Store: 500 Gallon Each Side

Fleet Size	32
Annual Operating Hours Each	360
Fuel Use Gal/Hrs	538.4
Fuel Cost/Gallon	.80¢
Annual Fuel Costs Total Fleet:	$6,202,368.00

ARMY-VH-60A
External Store
One (1) — 230 Gallon Each Side
One (1) — 450 Gallon Each Side

Fleet Size	400
Annual Operating Hours Each	224
Fuel Use Gal/Hrs	130.7
Fuel Cost/Gallon	.80¢
Annual Fuel Costs Total Fleet:	$11,710,720.00

Sundowner Flight Test Program

On September 15, 1981 a Beechcraft Sundowner became the first aircraft to operate on liquefied methane. The aircraft is used extensively as a student trainer, and one of the objectives of the flight test program was to determine how much operating costs could be reduced using methane as a fuel. The results were impressive and are summarized below:

Aircraft: Sundowner
Annual Operating Hours: 600
Hourly Fuel Consumption (Cruise): 10.4 Gallons

	Av-Gas	LM
Fuel Use: Per Day Gallons (600 hrs ÷ 262 days = 2.29 hrs/day)	23.8	23.8
Fuel Cost: Per Gallon	$2.05	$0.65
Per Hour	21.32	$6.76
Per Day	$48.81	$15.47
Fuel Use Per Year, Gallons	6240	6240
Fuel Cost Per Year	$12,792	$4,056
Annual Savings Per Aircraft	$8,736.00	
Conversion Cost	$15,000.00	
Simple Pay Back	1.7 Years	

Engine Test Stand Results

Engine timing was advanced from 25 degrees to 35°B.T.D.C. to compensate for the 130 octane methane. This change in timing also reduced exhaust gas temperatures. Cruise power conditions were easily achieved and specific fuel consumption was improved.

The Sundowner range, speed and endurance characteristics while operating on liquefied methane are almost identical to those achieved with Av-Gas. The major difference in performance is a slight increase in takeoff distance and time to climb to altitude.

At full throttle, engine horsepower was down approximately 9%. This was attributed to the vaporized methane displacing about 10% of the normal air flow into the engine. As stated earlier, the specific fuel consumption showed improvement in all test runs. Economy cruise power conditions verify a significant reduction in hourly operating fuel costs. Table IV below summarizes the engine test stand results:

TABLE IV
SUNDOWNER ENGINE TEST STAND RESULTS

Test Conditions	Av-Gas			LM		
RPM	2700	2450	2350	2650	2450	2350
Horsepower	136.4	101.5	88.7	125.1	99.8	90.6
Fuel Flow (LB/HR)	76.0	58.3	53.9	54.2	42.0	32.8
(Gallons)	12.3	9.4	8.7	15.3	11.8	9.2
S.F.C. (LB/HP/HR)	.557	.580	.608	.443	.421	.362
Horsepower (Standard day Conditions)	179.9	105.6	92.3	161.7	103.8	92.6

The Sundowner aircraft is powered by a Lycoming 0-360 four cylinder engine rated at 180 horsepower. Two eighteen gallon liquefied methane fuel tanks were installed internally in the aircraft cabin in space normally occupied by the rear passenger seats. Fuel system components include: a fuel control valve, an air/methane heat exchanger, a pressure regulator and a fuel-air mixer. These components and the fuel system schematic are shown below.

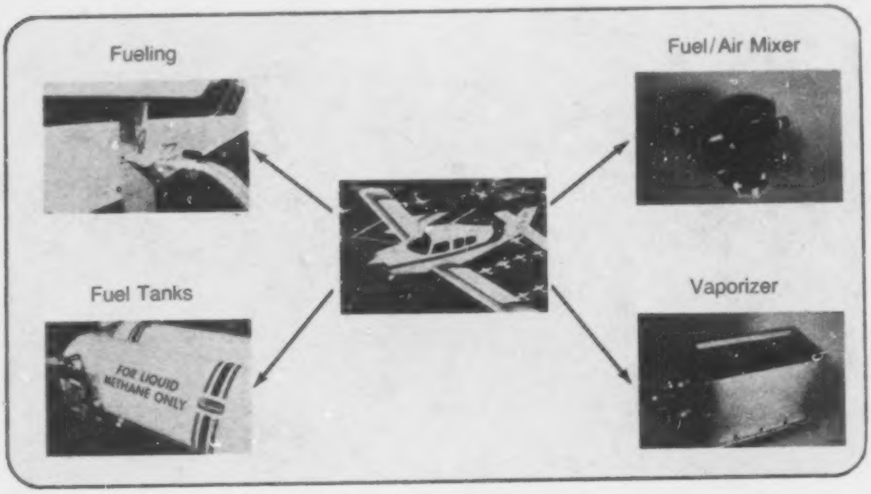

Fueling
Fuel/Air Mixer
Fuel Tanks
FOR LIQUID METHANE ONLY
Vaporizer

FIGURE II.
SYSTEM COMPONENTS

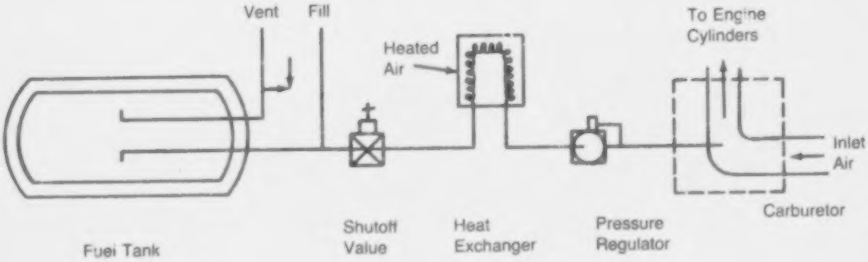

Vent
Fill
Heated Air
To Engine Cylinders
Inlet Air
Carburetor
Fuel Tank
Shutoff Value
Heat Exchanger
Pressure Regulator

FIGURE III.
SYSTEM SCHEMATIC

TH-55 Helicopter Program

The U.S. Army awarded a contract to Beech Aircraft in June, 1982 to conduct a "concept evaluation" for using liquefied methane as an aviation fuel in their primary trainer helicopter, the Hughes TH-55. This aircraft, like the Beechcraft Sundowner, is also powered by a Lycoming 0-360-BIA four cylinder engine rated at 180 horsepower. For the TH-55 conversion, the existing external fuel tank is removed and replaced by the liquefied methane fuel tank. Very minor changes were made to the aircraft in attaching the new fuel tank. The program plan was divided into three phases.

Phase I: System Design and Engineering

This phase was accomplished by Beech engineers at Boulder, Colorado and was completed in late 1982.

Phase II: System Test and Evaluation

This phase was a joint effort by Beech and the Army and was accomplished at Fort Rucker, Alabama and is essentially complete at this time. Airworthiness environmental testing of all fuel system components was accomplished by the Air Force at their test facilities at Eglin A.F.B., Florida. Engine test stand runs have been completed on both Av-Gas and liquefied methane, and analysis of this data is in progress.

Phase III: Flight Test Operations

This phase will be accomplished by the Army at Fort Rucker, and is scheduled to start the first week in September. Flight test parameters will include the same basic maneuvers and duplication of the Army's training sortie. This phase will conclude the "concept evaluation" by the Army, and will determine the operational suitability of the fuel system.

As in the case of the Sundowner, the hourly operating costs of the TH-55 are reduced dramatically. Fuel cost savings and system payback estimates for the entire TH-55 primary trainer fleet of 144 aircraft are summarized as follows:

Aircraft: TH-55
Annual Operating Hours: 786
Daily Operating Hours: 3.0

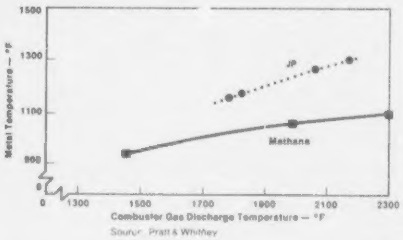
		AV-Gas	LM
Fuel Use:	Per Hour	13.0	14.9
	Per Day	39.0	44.7
Fuel Cost:	Per Gallon	1.60	.42¢
	Per Hour	$20.80	$ 6.26
	Per Day	$62.40	$18.77
	Per Year	16,348.80	$4,918.79
Annual Savings:	Per Aircraft	$11,430.01	
	144 Aircraft	$1,645,921.40	
Conversion Cost (est)		$20,000 each	
Simple Payback		1.7 years	

Almost any existing military or commercial aircraft may be converted to operate on liquefied methane. In many aircraft, the methane can be used in a dual-fuel configuration with the liquefied methane fuel tanks adapted to existing external stores on the aircraft.

General Electric, under contract to NASA, successfully demonstrated that their J-85 engine could be operated on either Jet-A or methane. Dual injectors were utilized, and during engine test stand runs the engine was switched back and forth from one fuel to the other with no disruption in engine operation.

The use of liquefied methane in turbine engines provides additional benefits in addition to reduced fuel costs of close to 60%. The −259°F heat sink of the fuel provides cooling to the engine bleed air that is used to cool the engine hot metal sections. Inlet combustion temperatures can be increased from the present 1600°F to close to 3000°F while the engine remains cooler than on JP-fuels.

LOWER COMBUSTOR METAL TEMPERATURES FOR METHANE FUEL



Source: Pratt & Whitney

NATURAL GAS OPERATING EXPERIENCE

Engine Type	J57
Running Time	Over 450,000 hr.
Present Turbine Inlet Temperature	1500°F
TBO at 1500°F	12,000 hr.
Maximum Continuous Turbine Temperature	1600°F
Maximum Intermittent Turbine Temperature	1725°F

Source: Pratt & Whitney

FIGURE IV.

By raising the inlet combustion temperatures, the turbine engine horsepower can be increased by over 20%. In over 450,000 hours of engine test runs on their J-57 powerplant in 1969, Pratt & Whitney also demonstrated that the engine life was increased 100%, and the time between overhaul (T.B.O.) went from 3,000 to 12,000 hours. Conversion of a turbine powered aircraft to operate on liquefied methane will be the next marketing priority after successful completion of the TH-55 program.

There is a growing world-wide interest in the potential of methane as a transportation fuel, and this interest is shared by the United States Congress, the Department of Defense, several major industries and municipal, county, and state governments. In addition to the ongoing automotive fleet conversions, Beech aircraft has also established specific near-term goals in the aviation sector that we hope to achieve. These include:

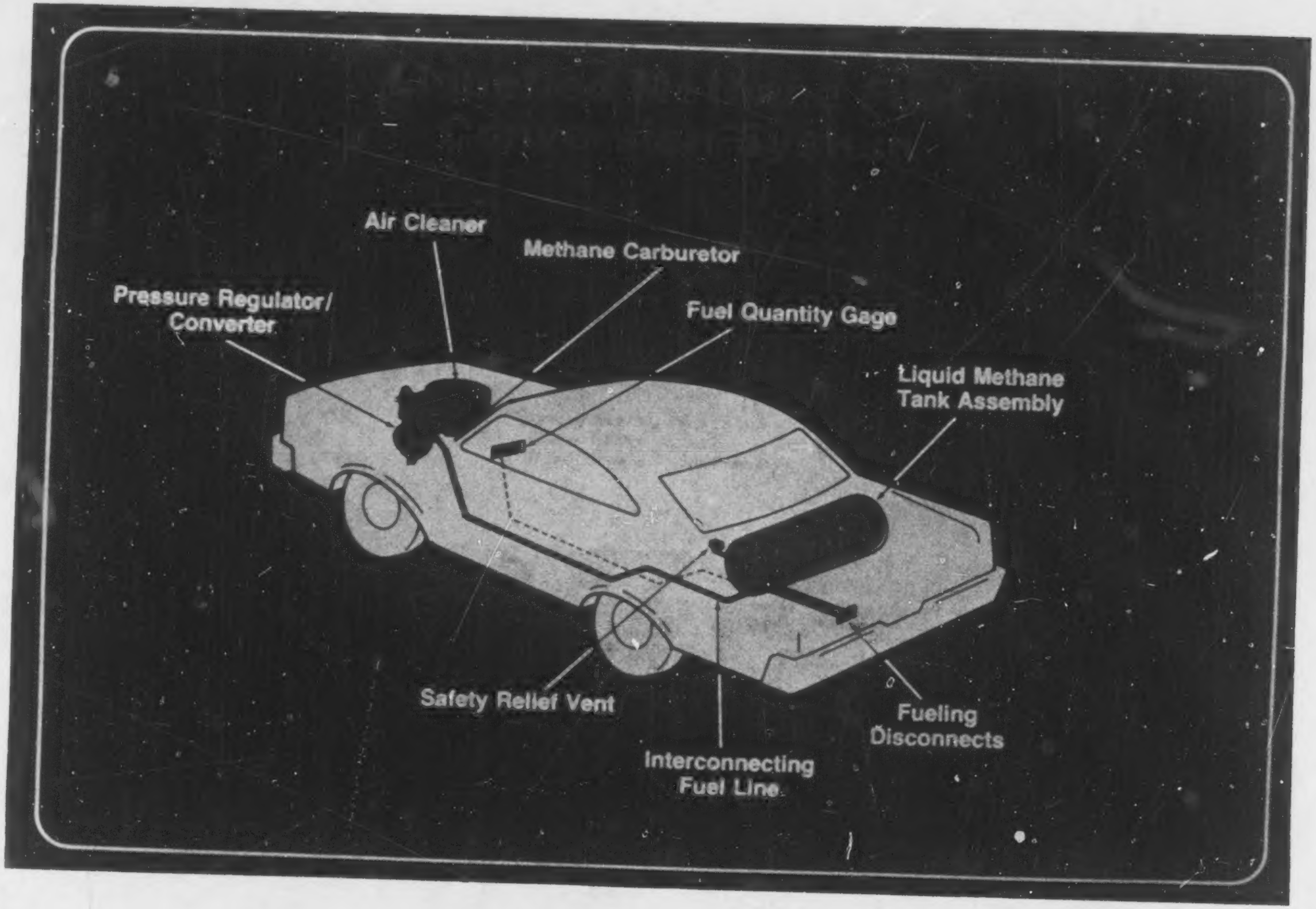
- D.O.D. certification of liquefied methane as an aviation fuel.
- Army airworthiness certification of the Beech liquefied methane fuel system
- Supplemental type certification (STC) of a liquefied methane fueled aircraft.

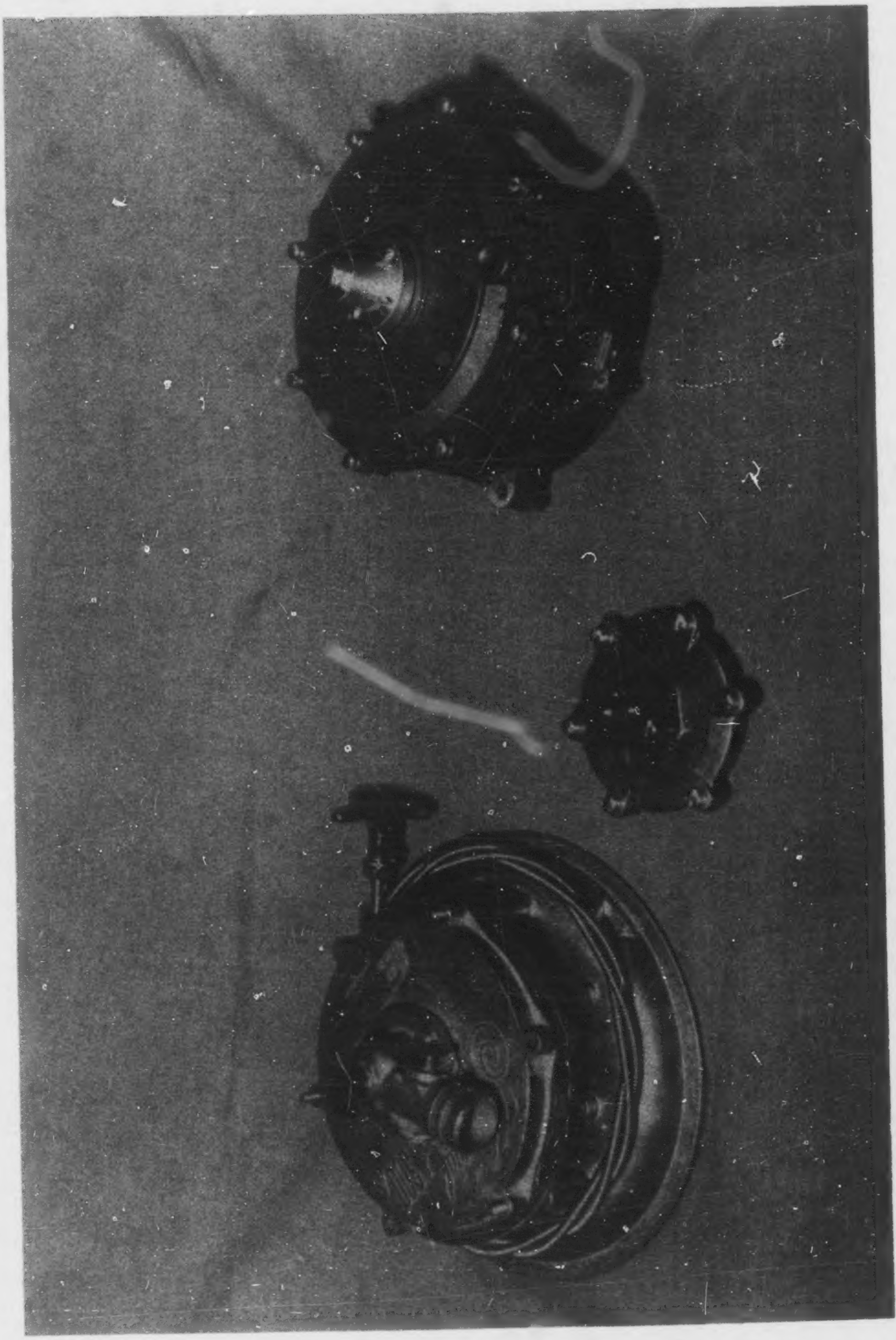
Each of the major energy grids in the United States, petroleum, electricity and pipeline gas matured and evolved over a period of sixty (60) years. By comparison, the first "LNG" plants came on stream in 1966 and have achieved modest growth since that time, primarily in industrial utilization, home heating and power generation. The "LNG" energy grid is now on the threshold of making the transition to the transportation sector. Beech Aircraft's marketing strategy is to facilitate this transition via the successful implementation of relatively small, cost-effective model projects that will provide the "user" with a distinct economic advantage and increased market share, through reduced fuel costs. It is hoped that this approach will accelerate the development and expansion of the methane "energy grid" infrastructure including methane production, transport, storage, distribution and end-use as a transportation fuel.

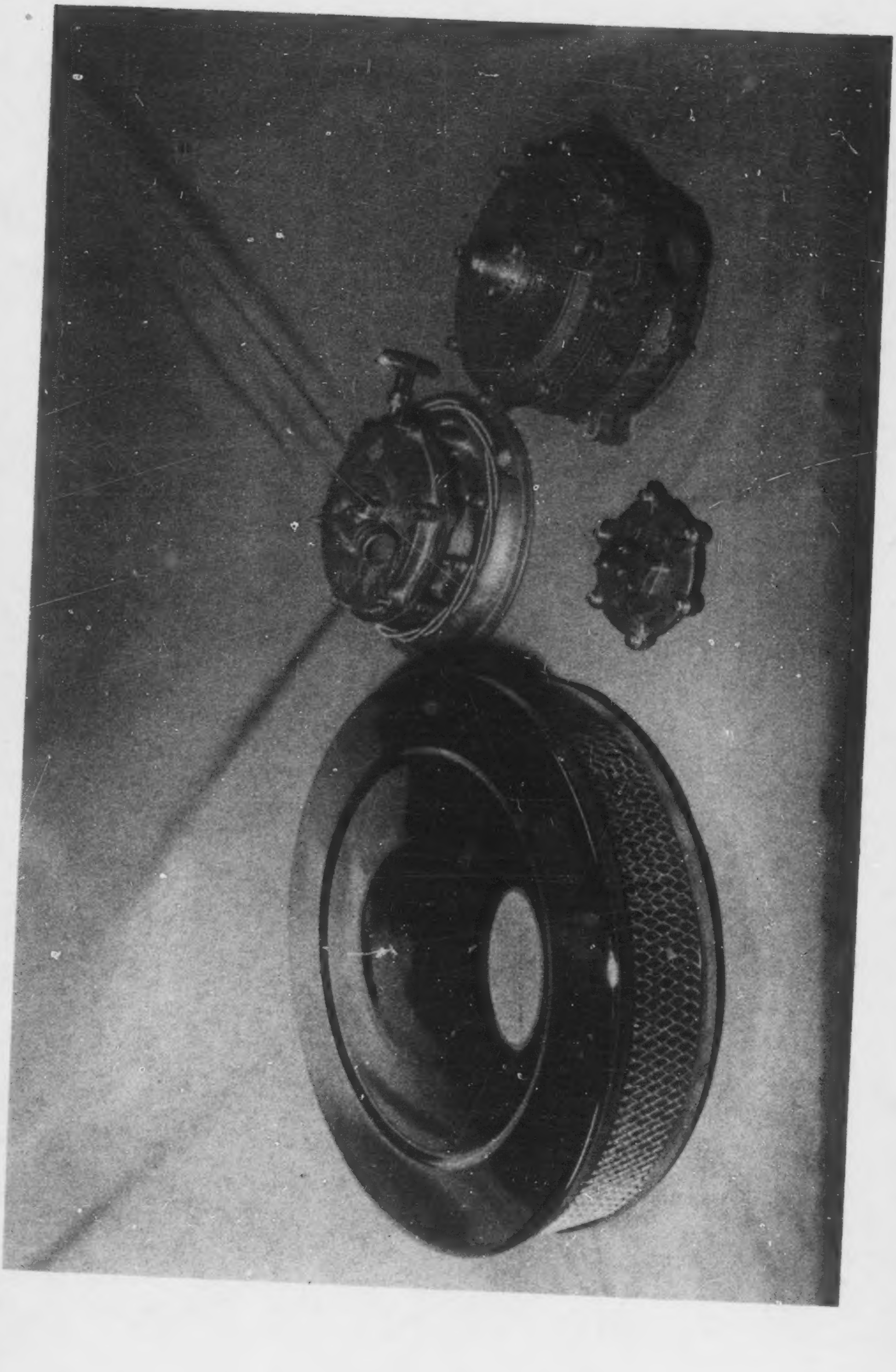
BEECH

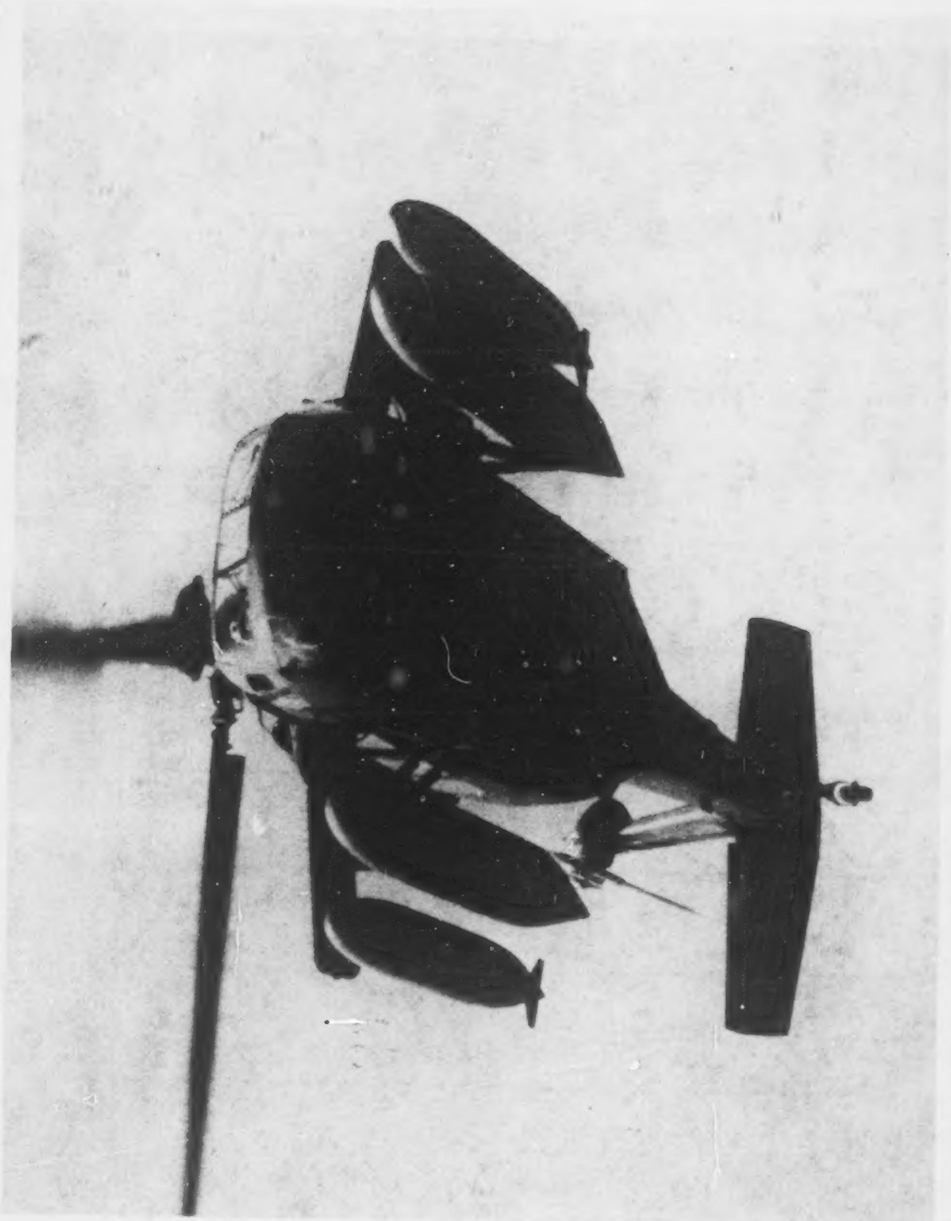
alternative energy

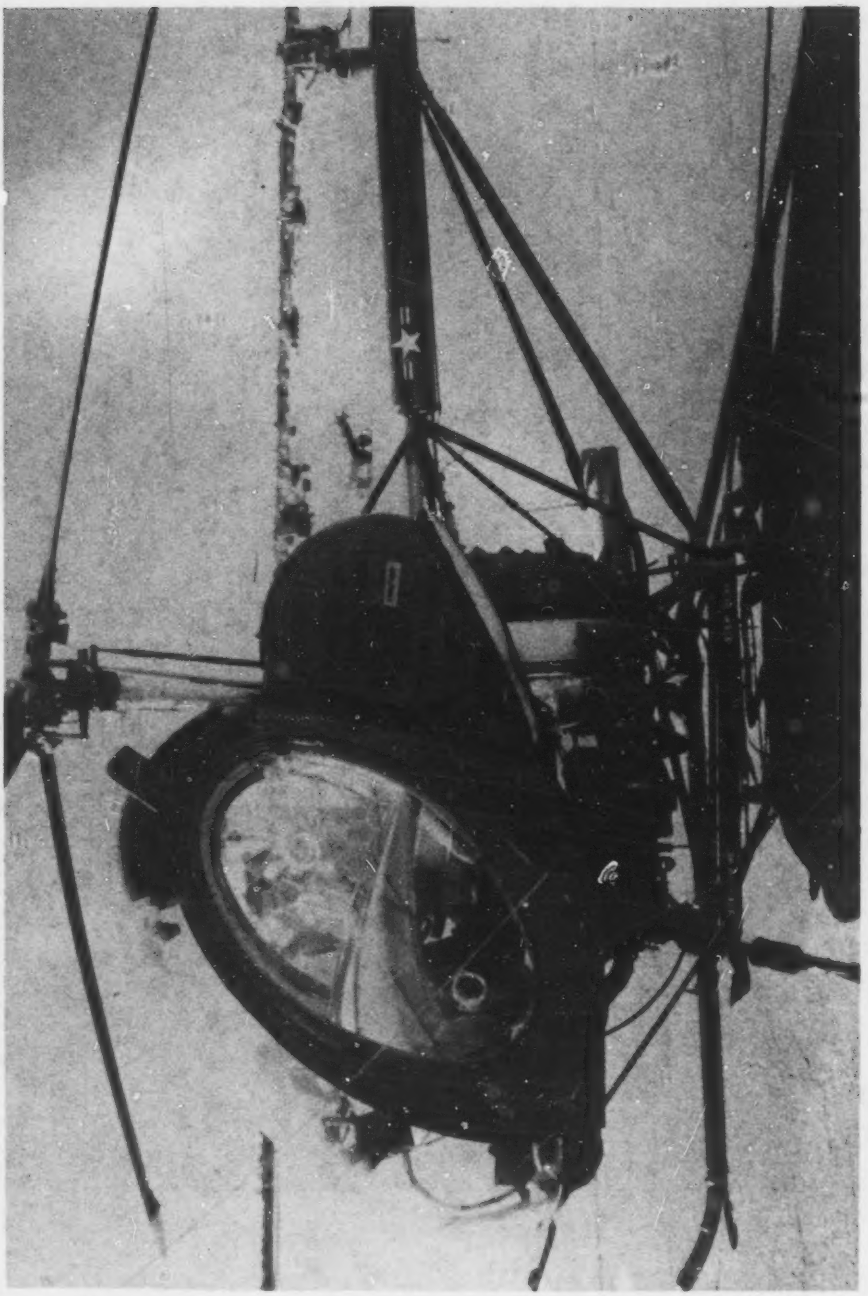
DIVISION

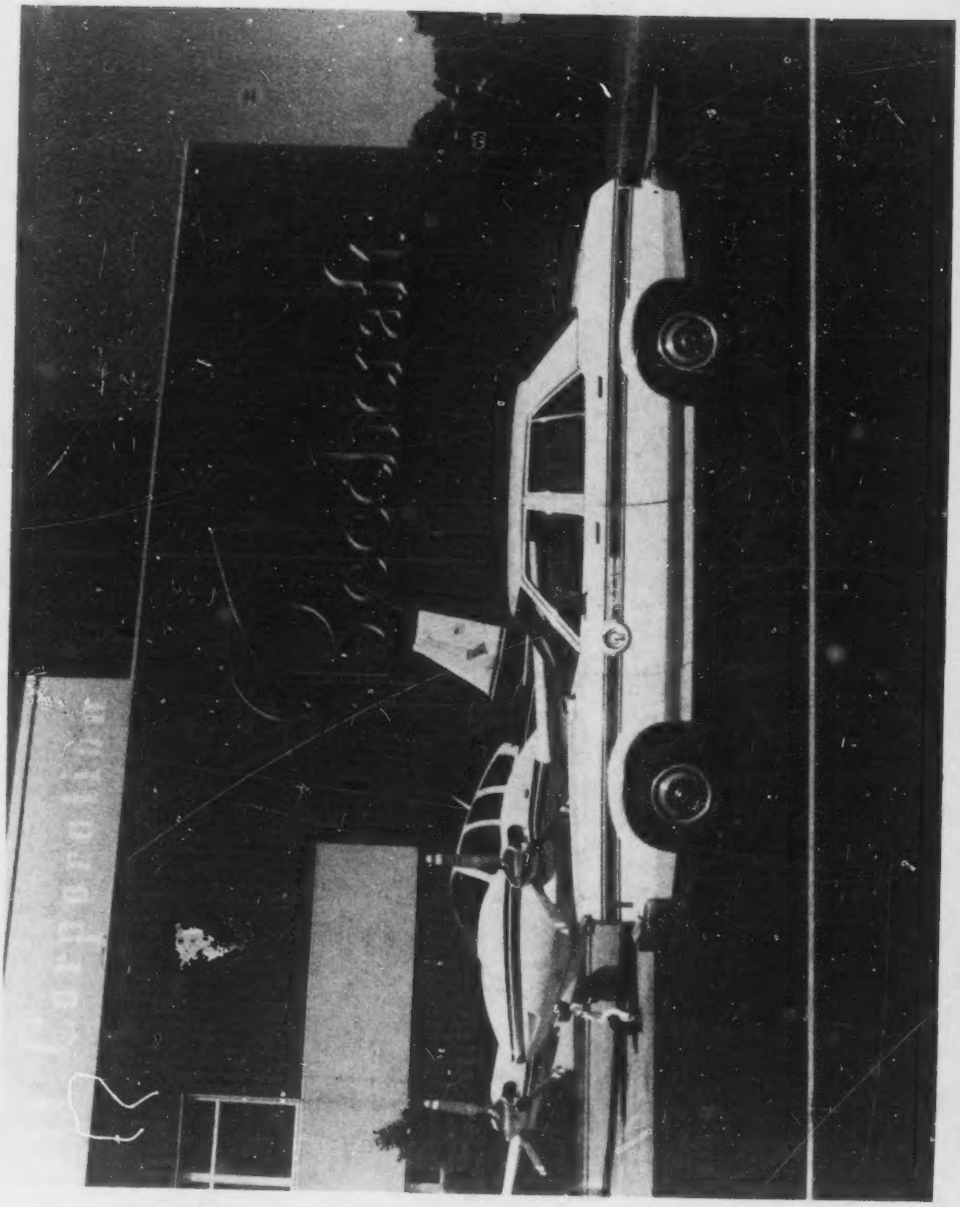

Air Cleaner
Methane Carburetor
Pressure Regulator/ Converter
Fuel Quantity Gage
Liquid Methane Tank Assembly
Safety Relief Vent
Fueling Disconnects
Interconnecting Fuel Line

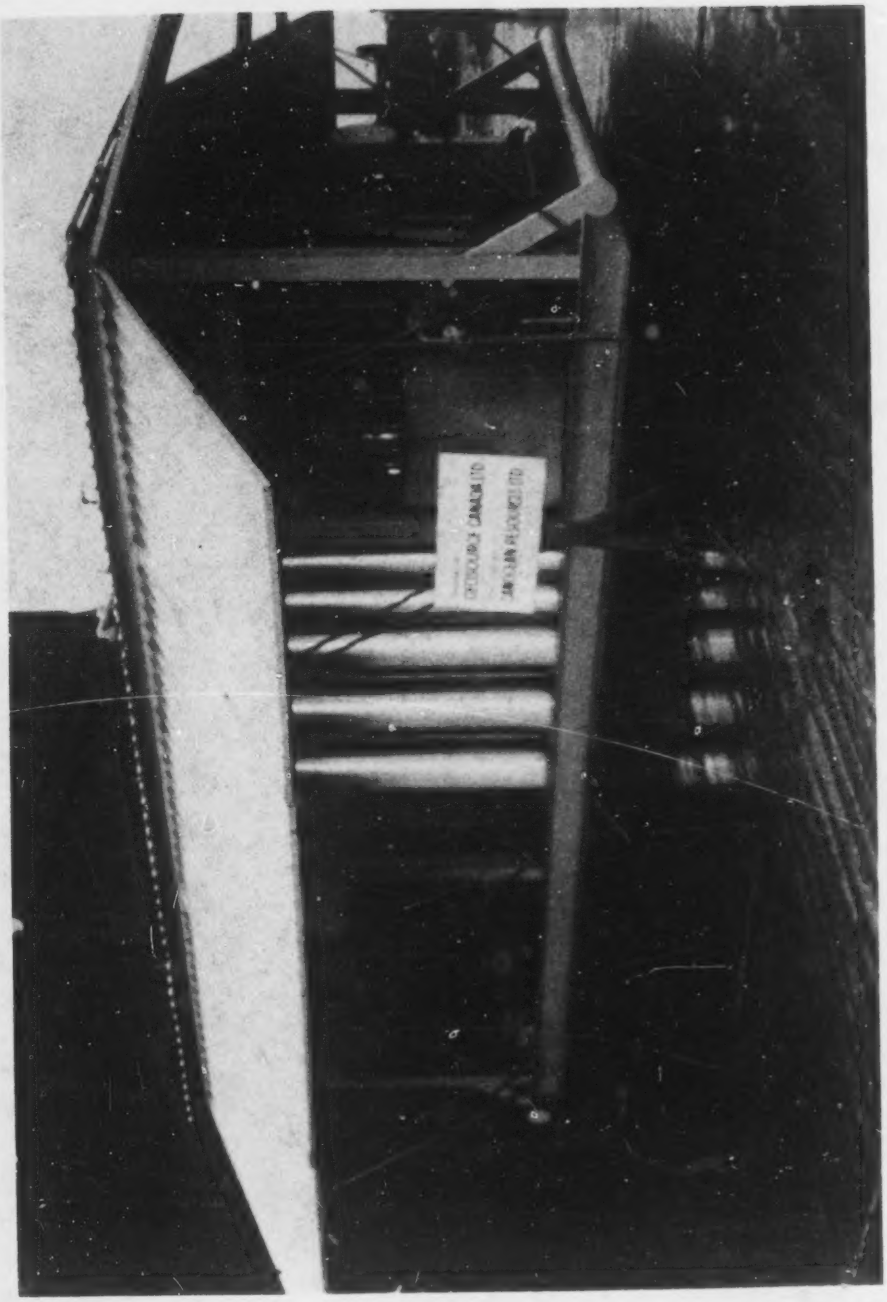


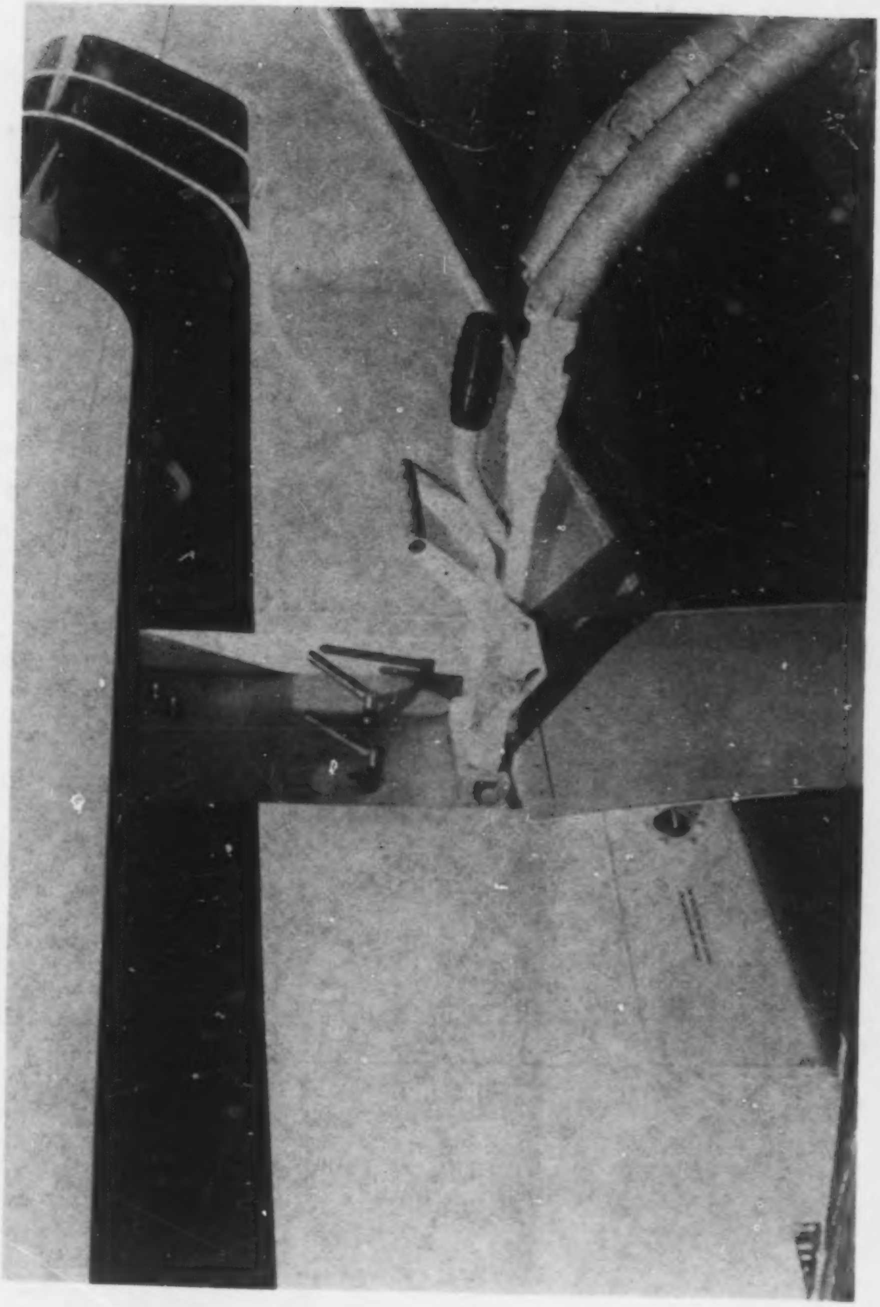


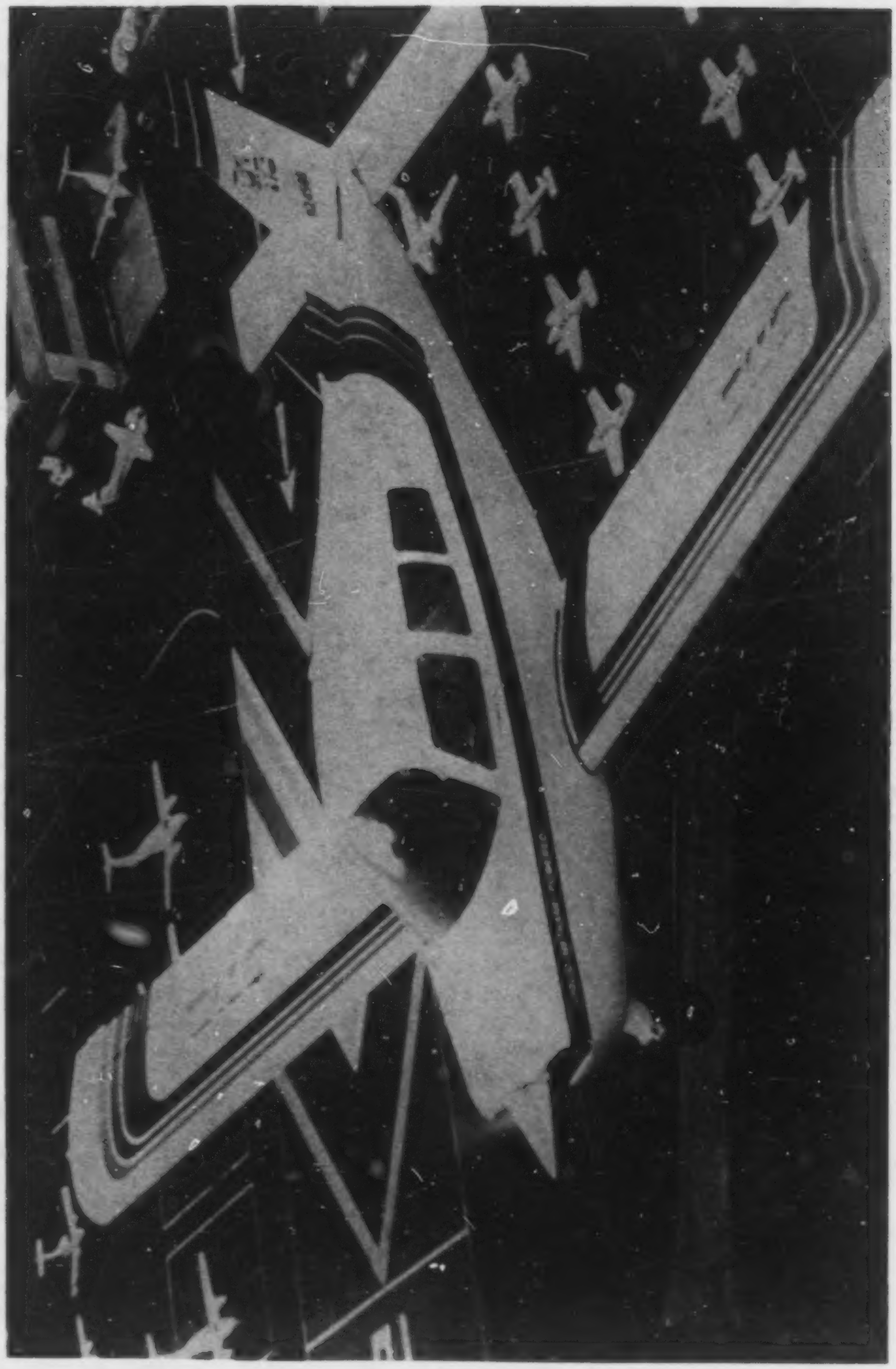


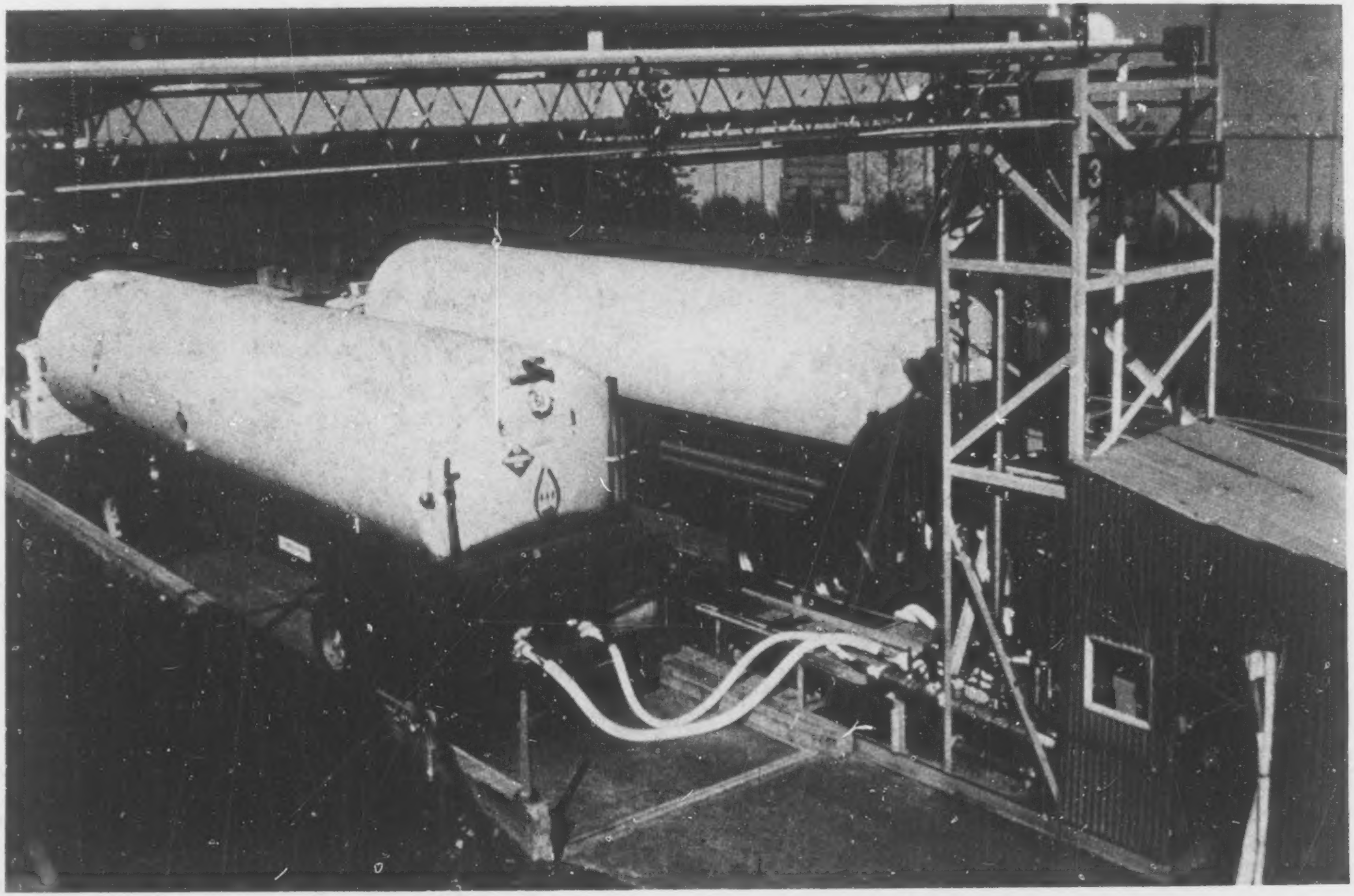



Beechcraft





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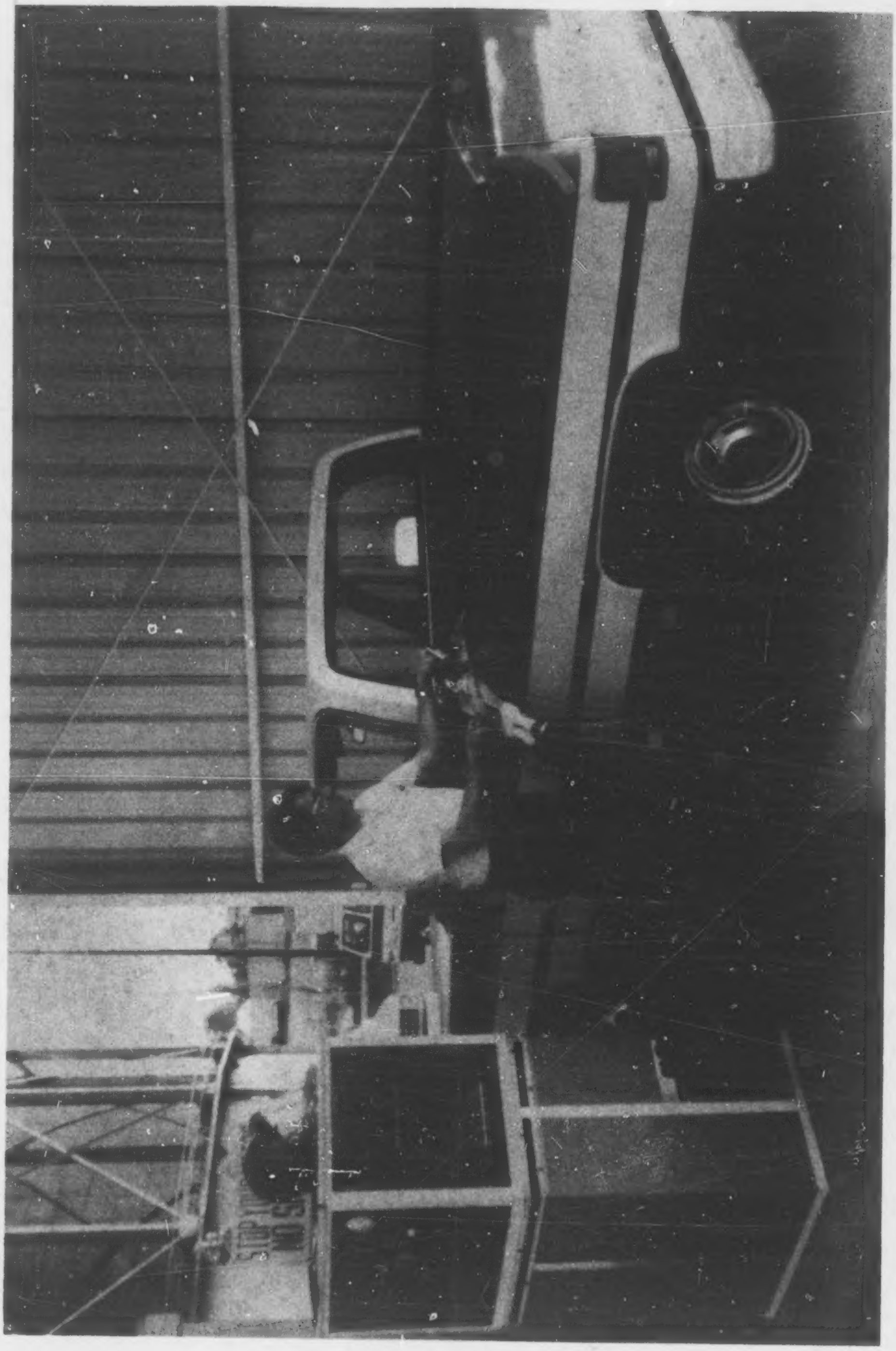
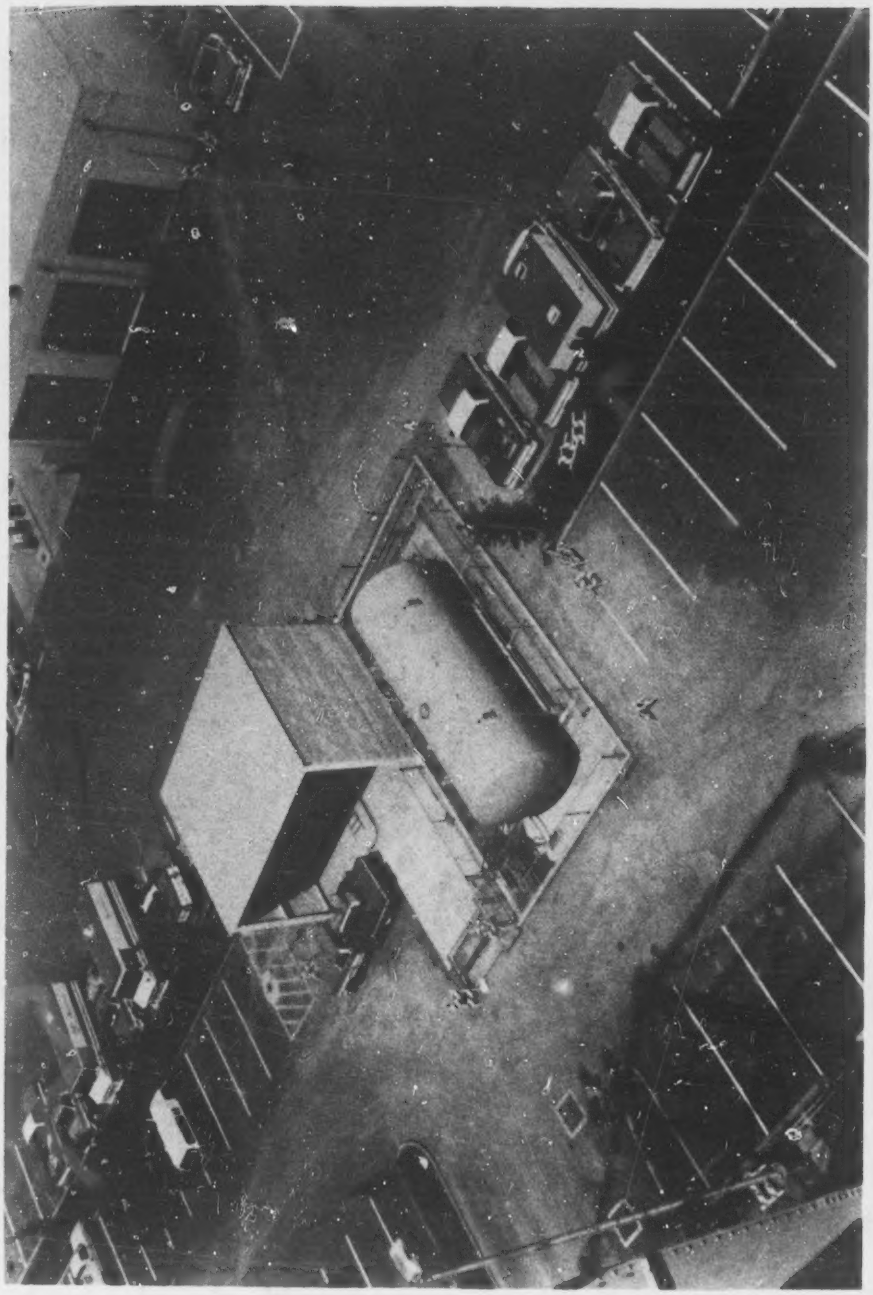




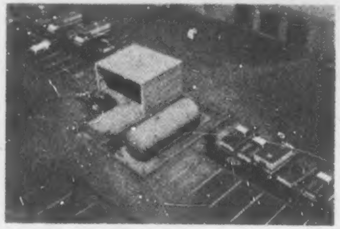
System Elements: Conventional Methane

Beechcraft

Alternative
Energy
Division

Systems
Design &
A&E

Fueling Station

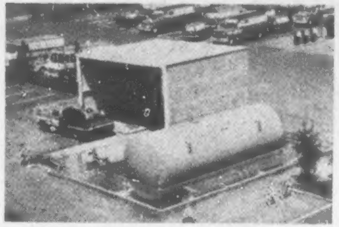


Design &
Fabricate

Dispenser

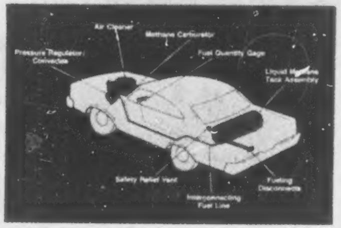
Buy &
Systems
Design

Bulk Storage

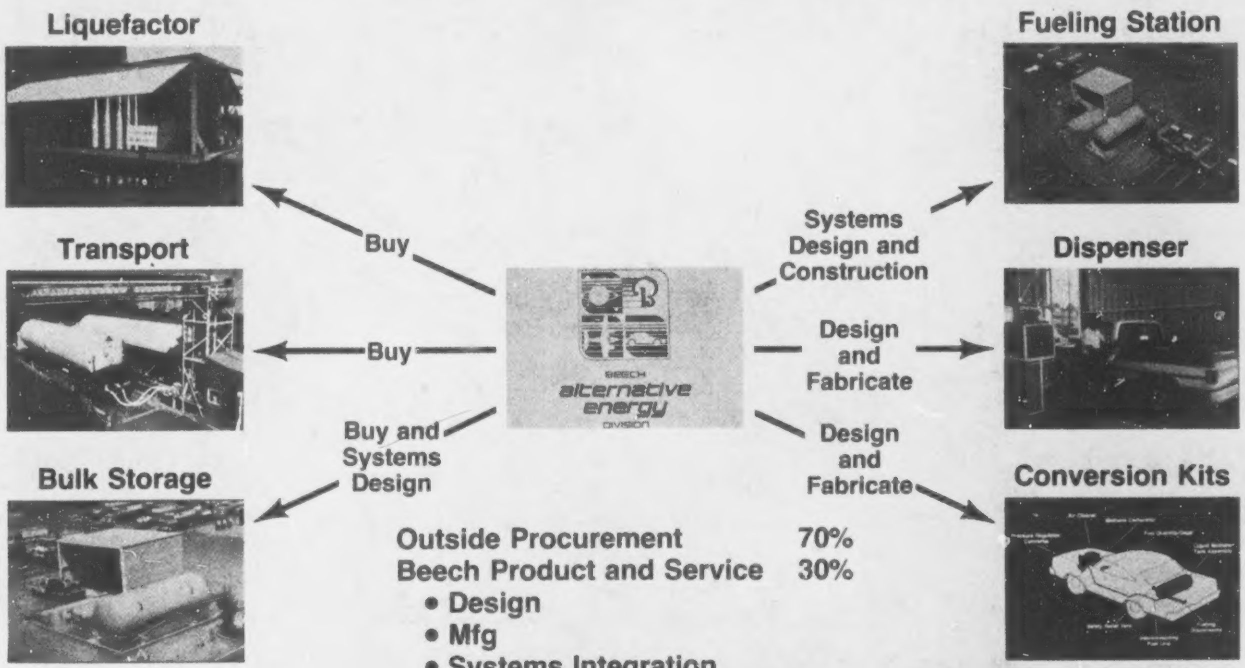


Design &
Fabricate

Conversion Kits


Air Cleaner
Methane Carburetor
Pressure Regulator/
Connector
Fuel Quantity Gage
Liquid Methane
Tank Assembly
Safety Relief Vent
Fueling
Disconnects
Interconnecting
Fuel Line

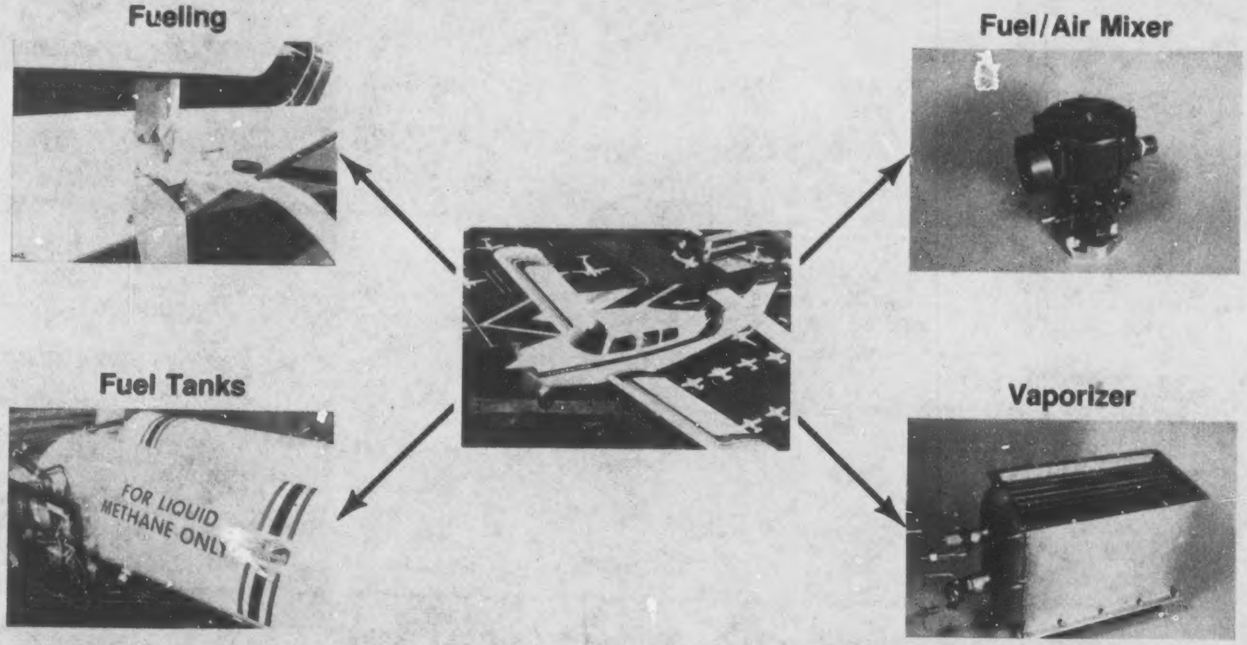
System Elements: Unconventional Methane


Liquefactor
Transport
Bulk Storage
Buy
Buy
Buy and Systems Design
BEECH alternative energy DIVISION
Systems Design and Construction
Design and Fabricate
Design and Fabricate
Fueling Station
Dispenser
Conversion Kits

Outside Procurement	70%
Beech Product and Service	30%

- Design
- Mfg
- Systems Integration
- Field Support

Light Aircraft Methane Conversion System


FOR LIQUID
METHANE ONLY

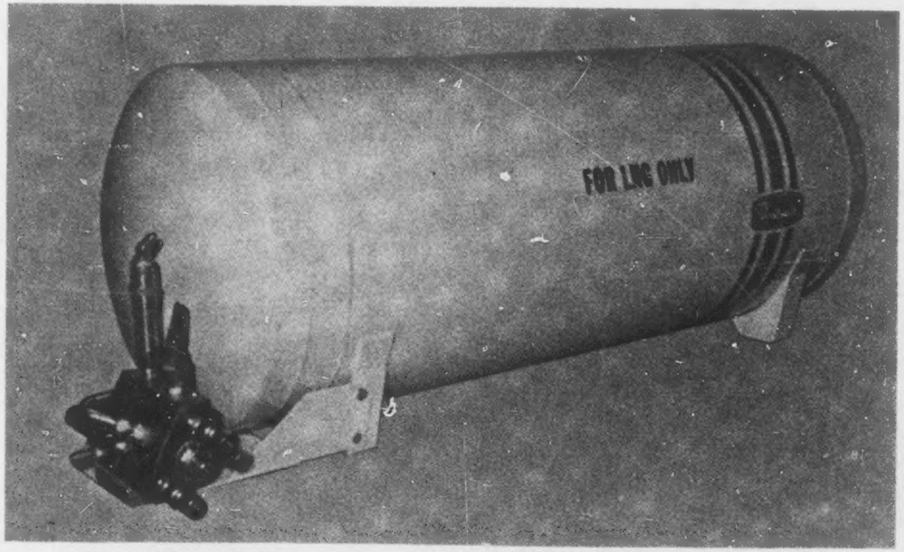
Fueling

Fuel Tanks

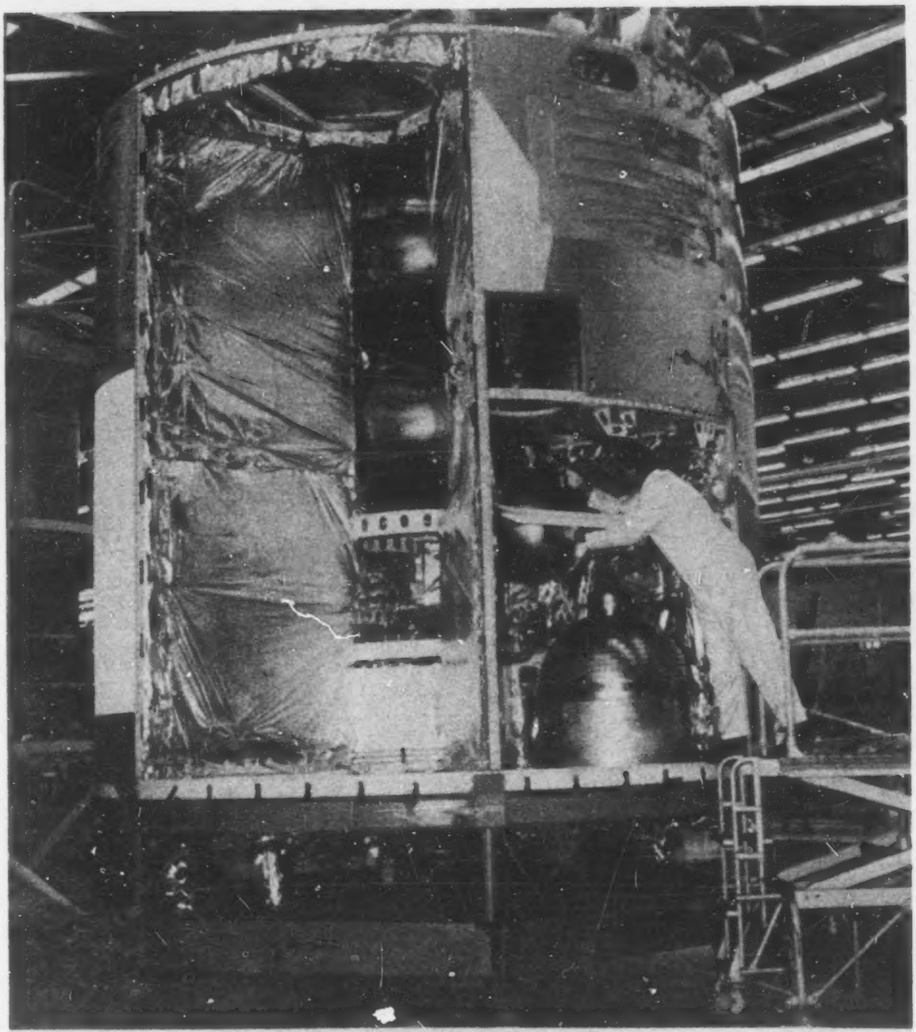
Fuel/Air Mixer

Vaporizer

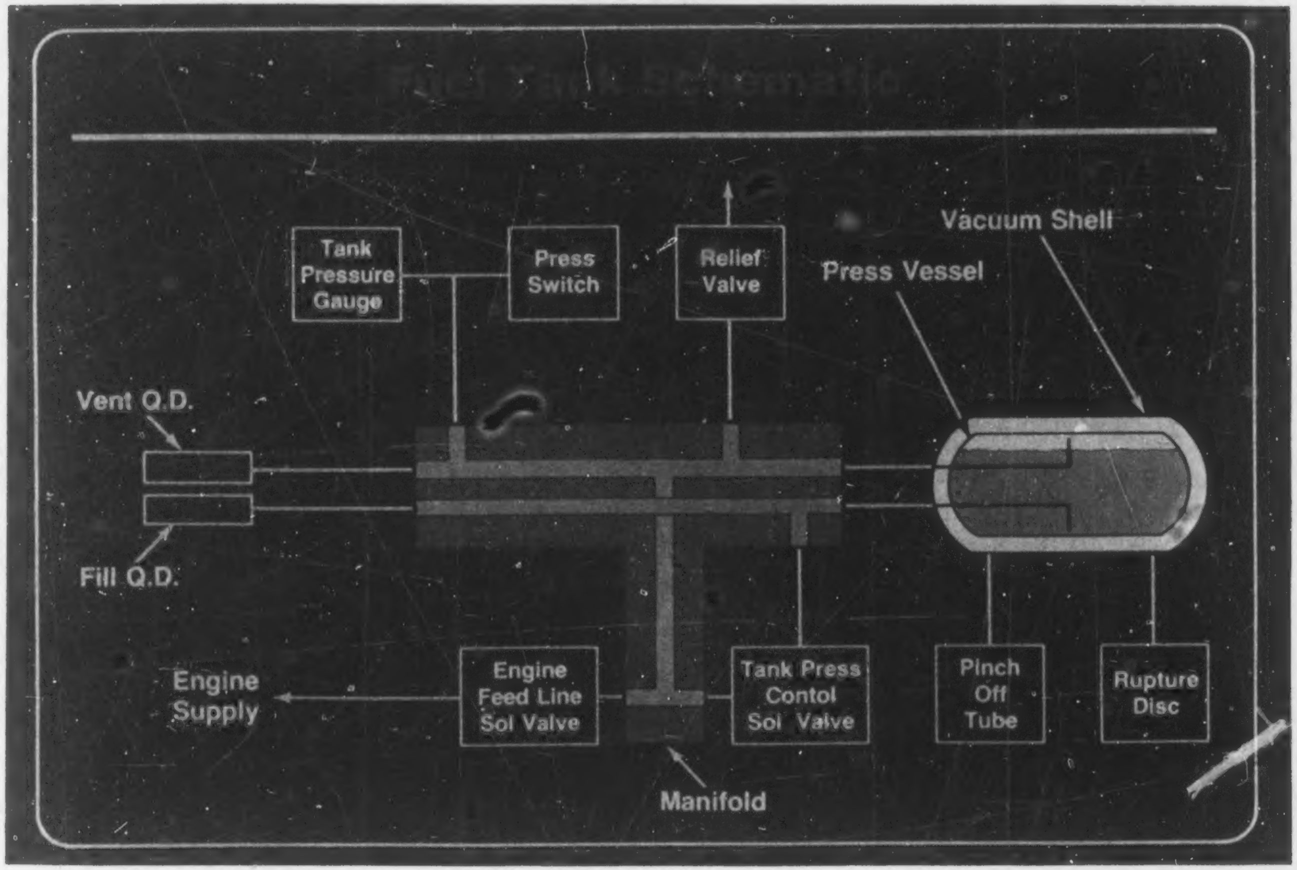
Fuel Tank

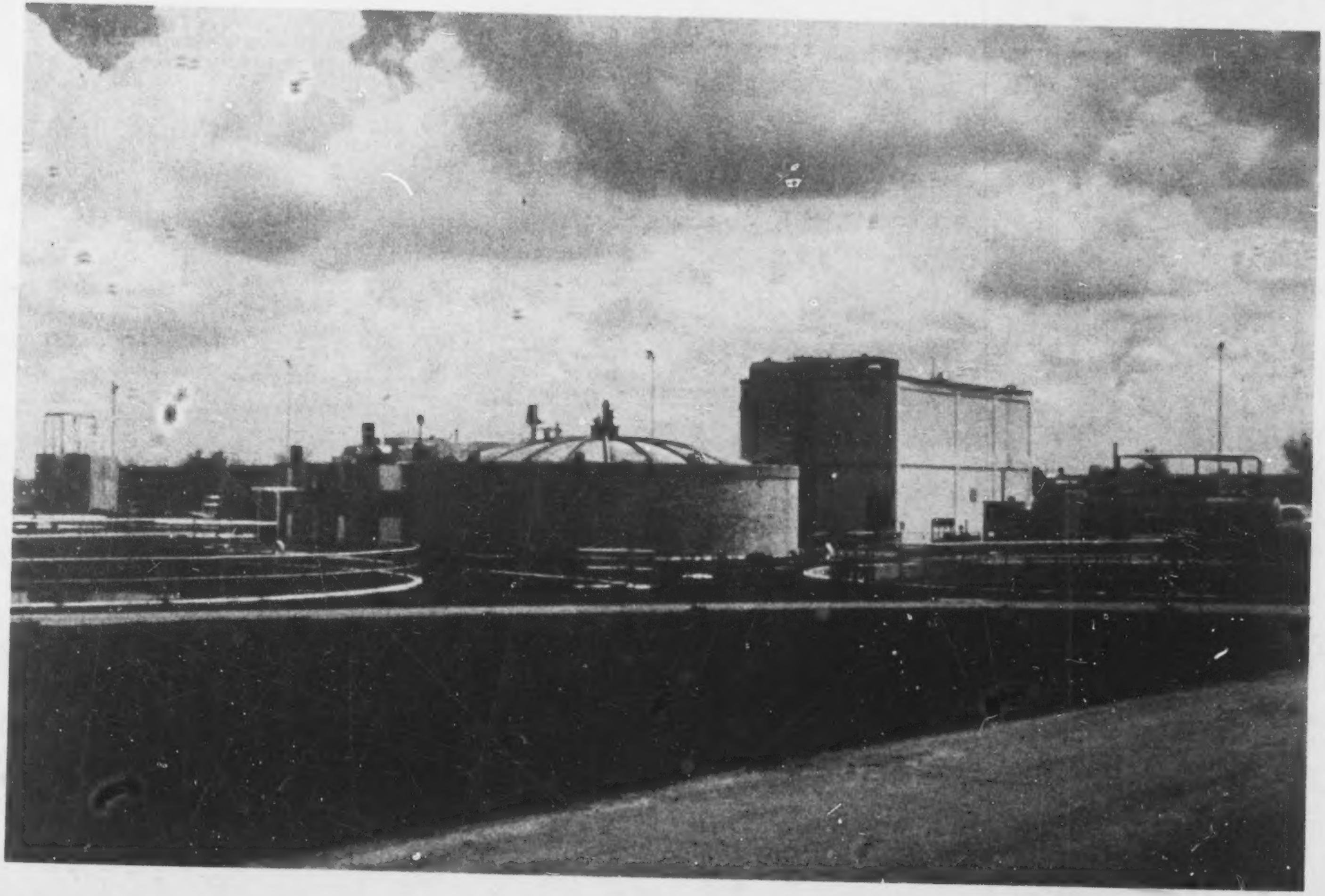


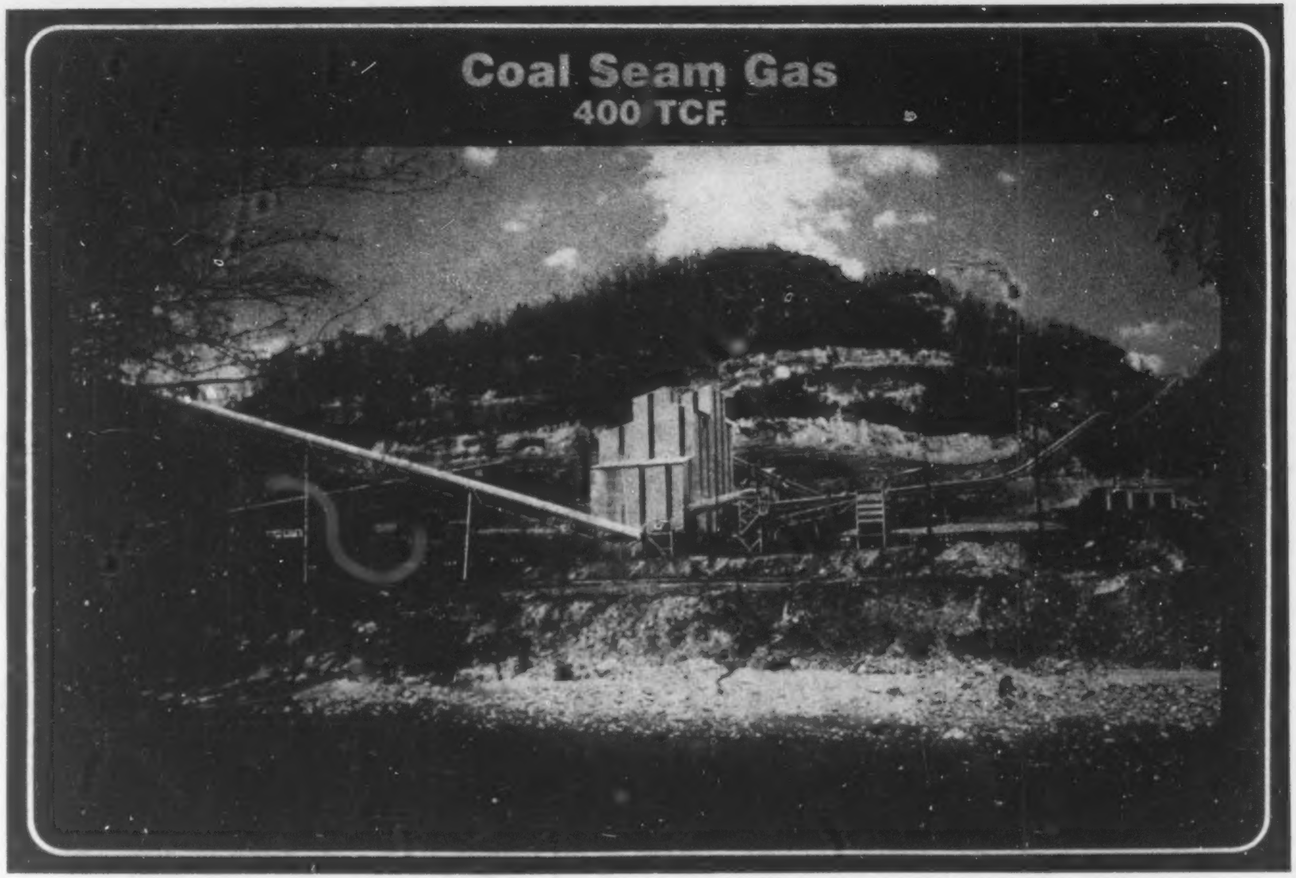
Size	18 Gallon
Operating Pressure	20 PSI
Service Life	10 Yrs or 200,000 Miles
Lock-Up Time	7 Days Without Venting
Vent Rate	1.0% Per Day



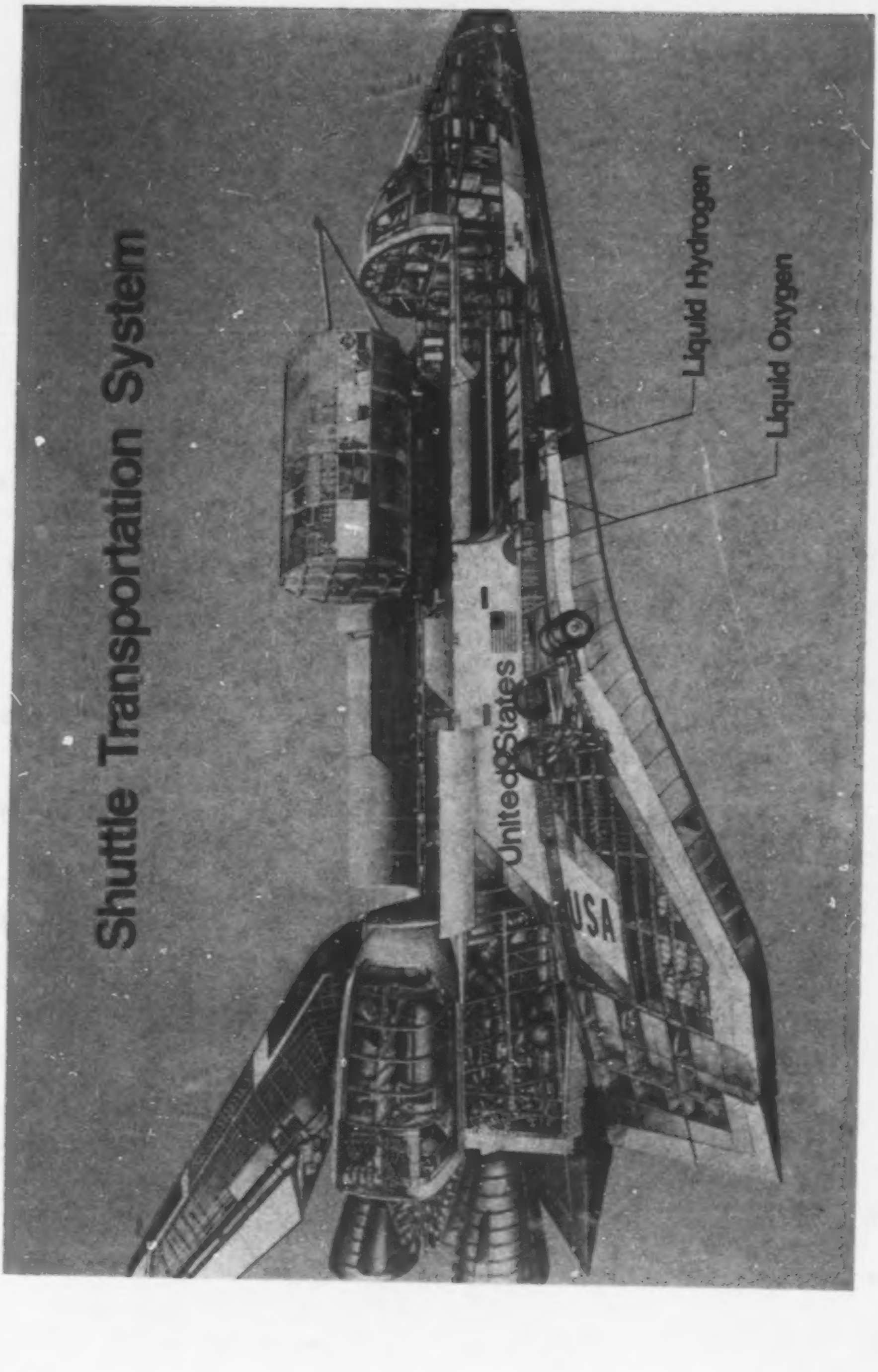
Beechcraft
Hydrogen and Oxygen Tanks
Apollo Spacecraft


Fuel Tank Schematic
Tank Pressure Gauge
Press Switch
Relief Valve
Press Vessel
Vacuum Shell
Vent Q.D.
Fill Q.D.
Engine Supply
Engine Feed Line Sol Valve
Manifold
Tank Press Contol Sol Valve
Pinch Off Tube
Rupture Disc



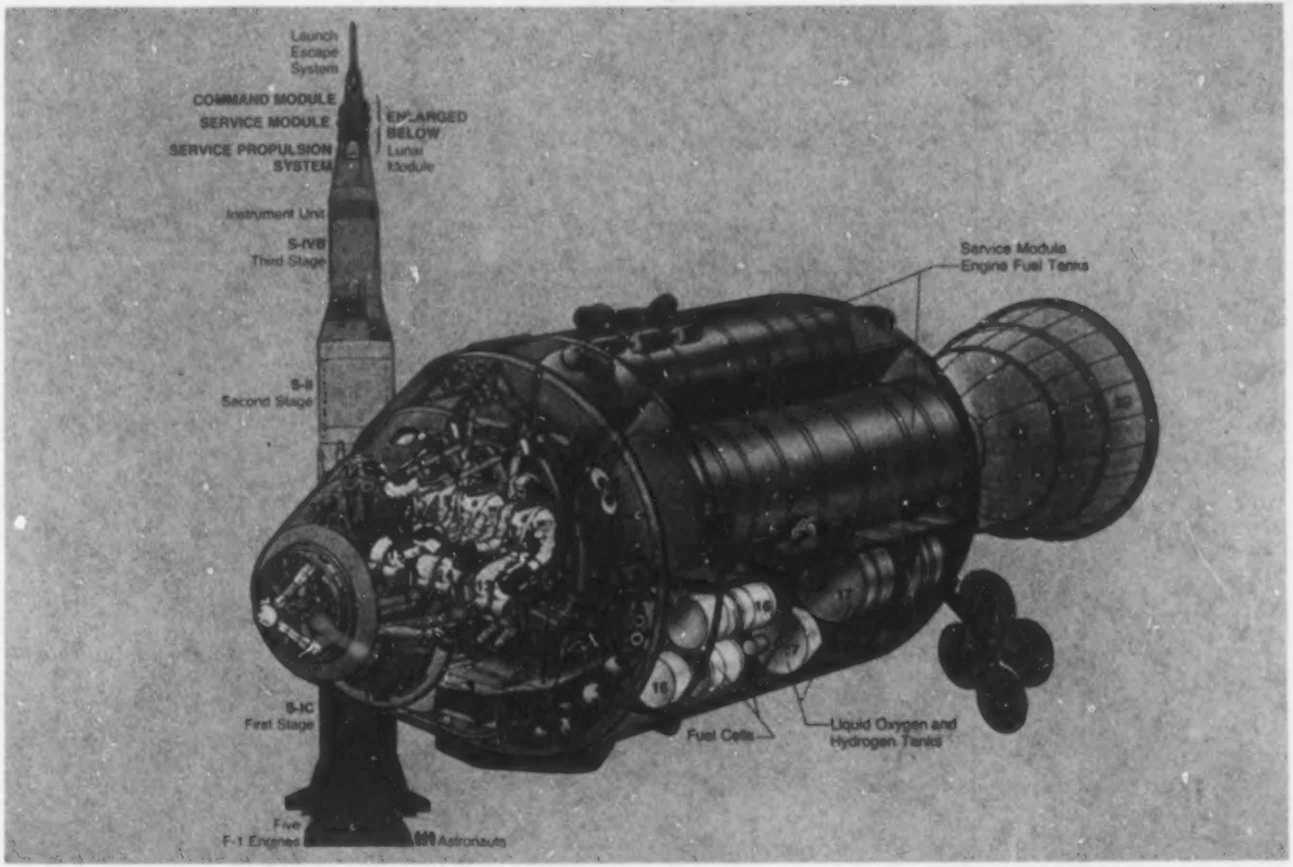


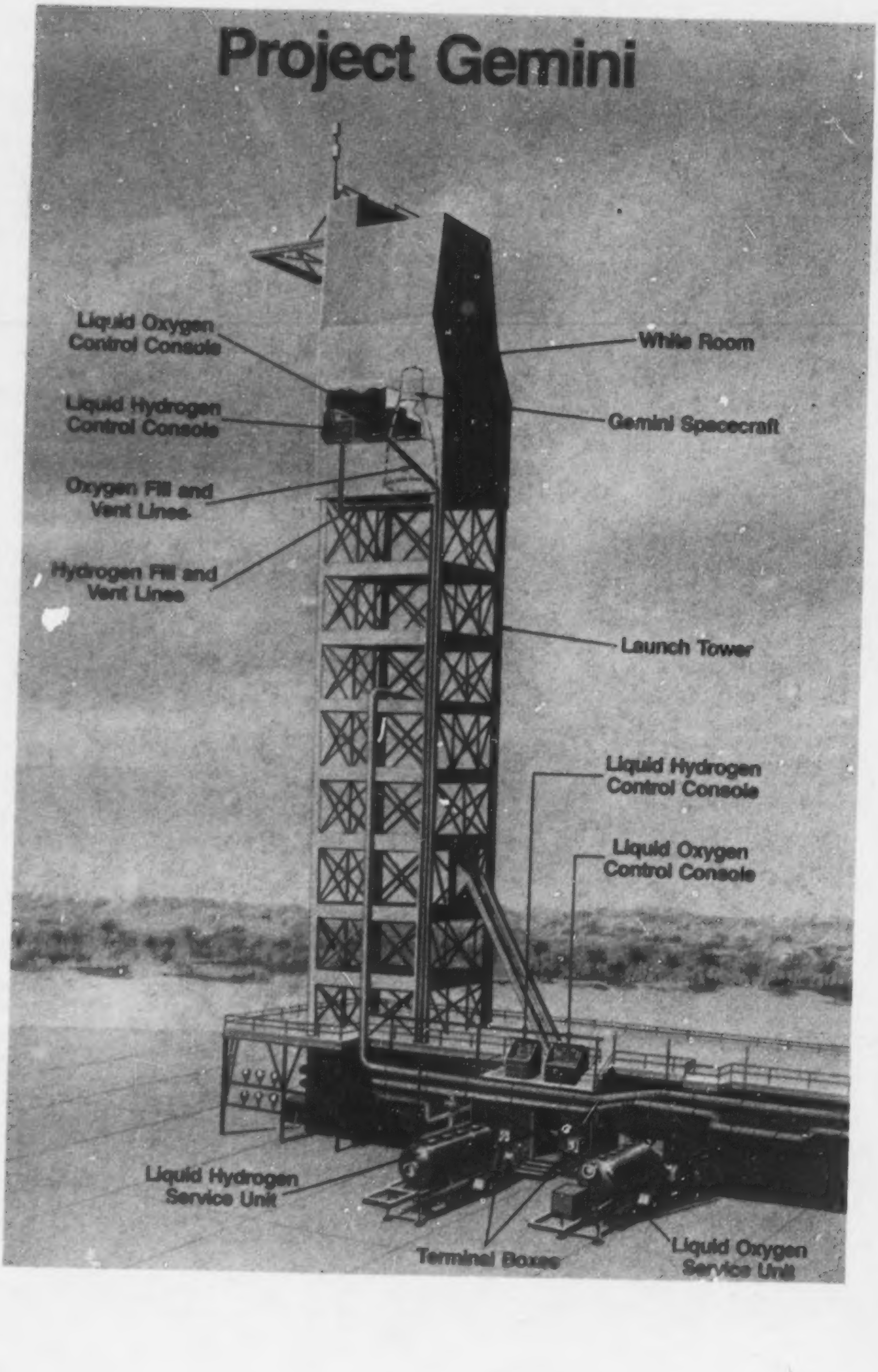
Coal Seam Gas
400 TCF

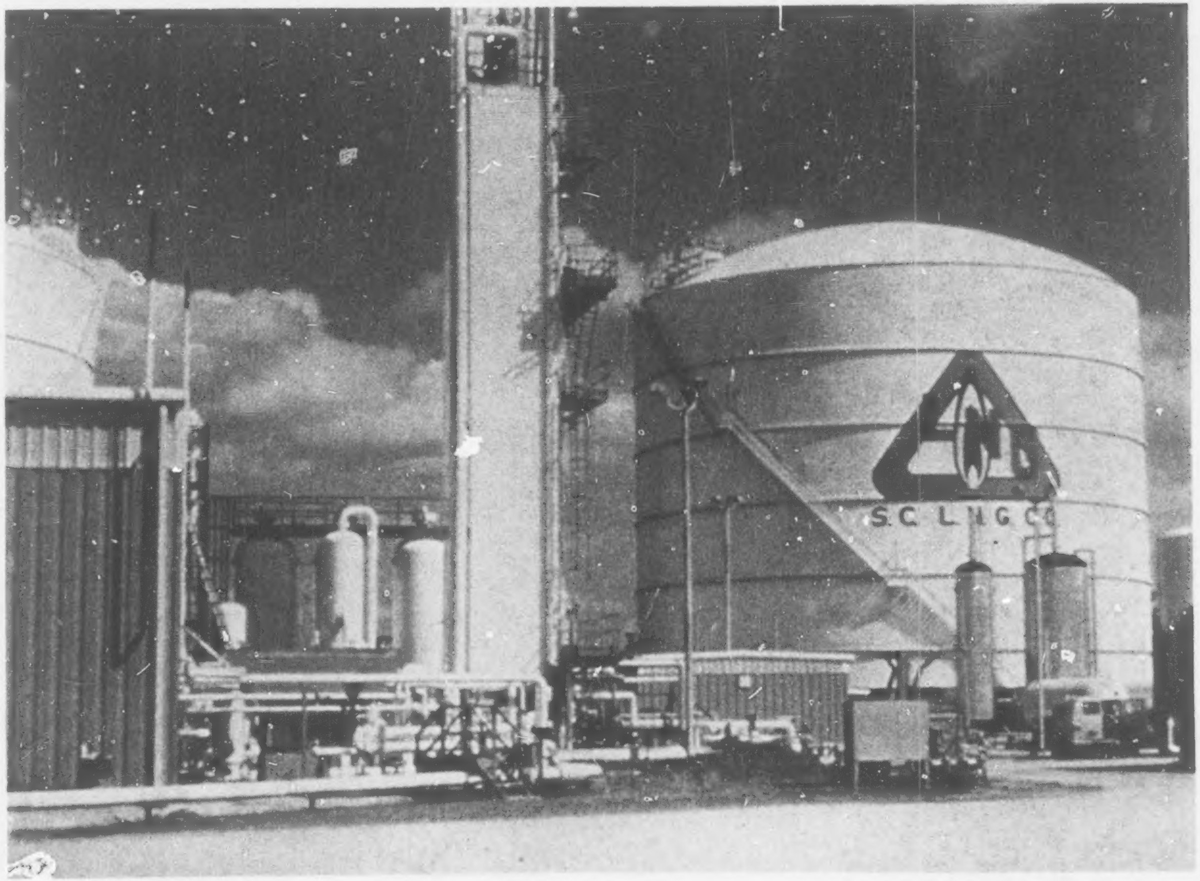


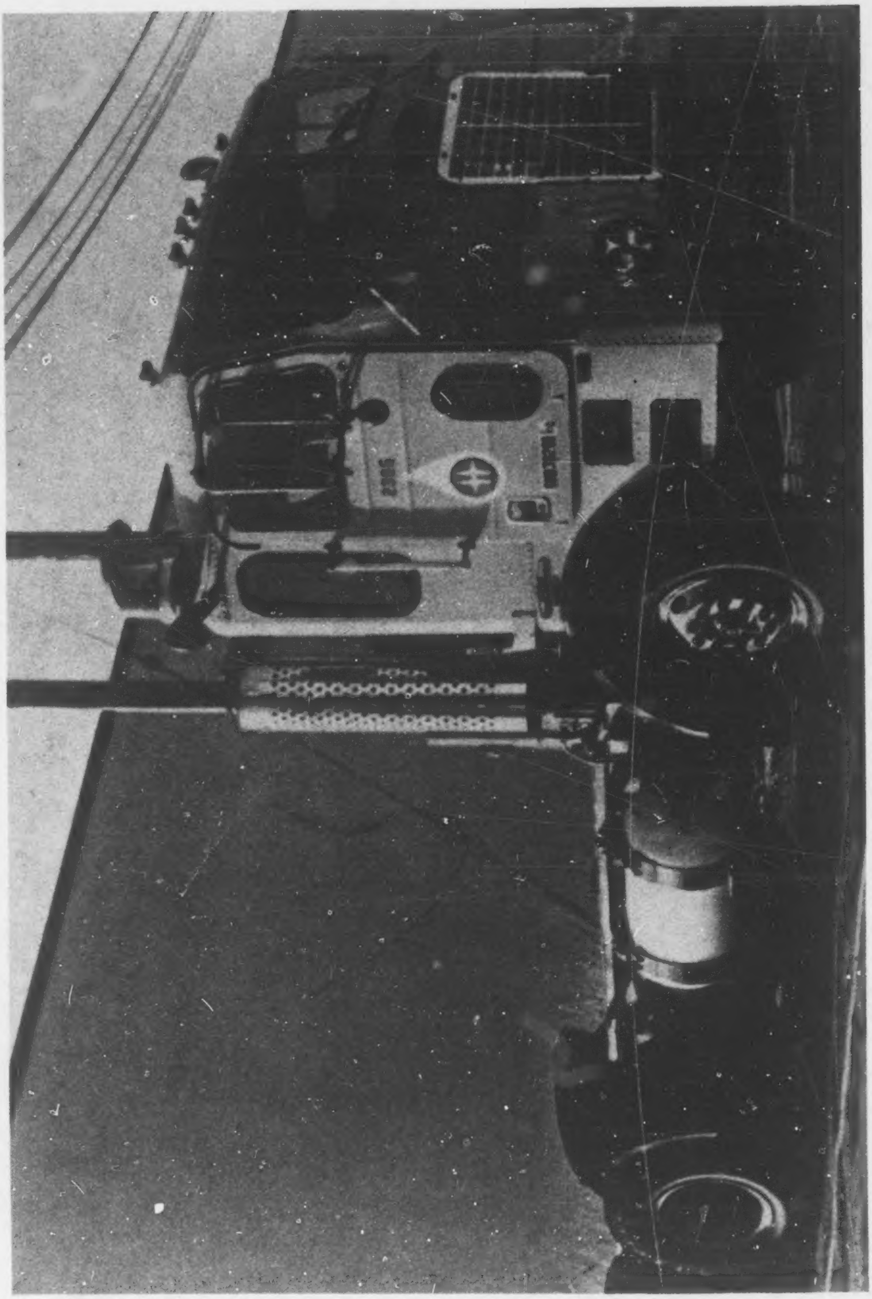
Shuttle Transportation System

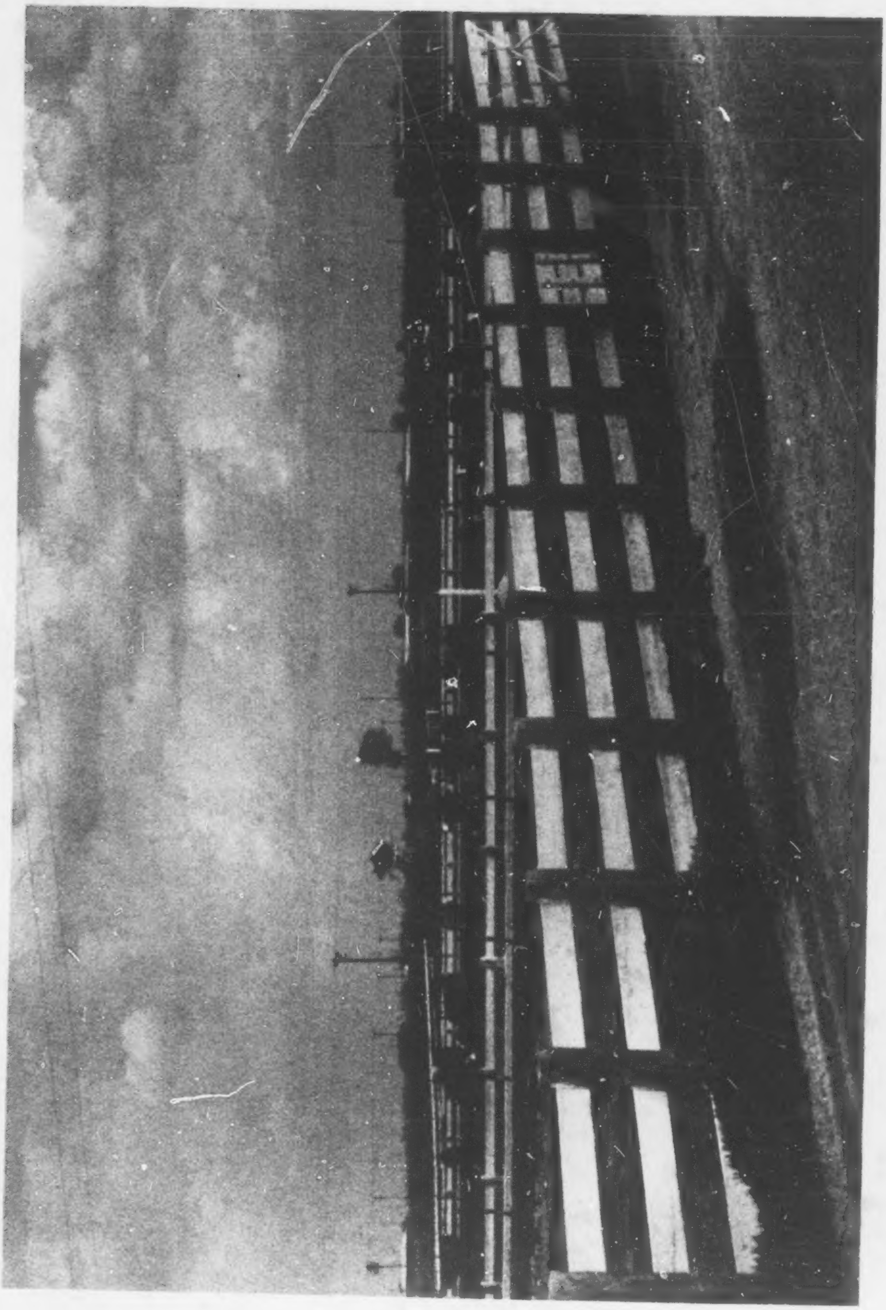
Liquid Hydrogen
Liquid Oxygen
United States
USA

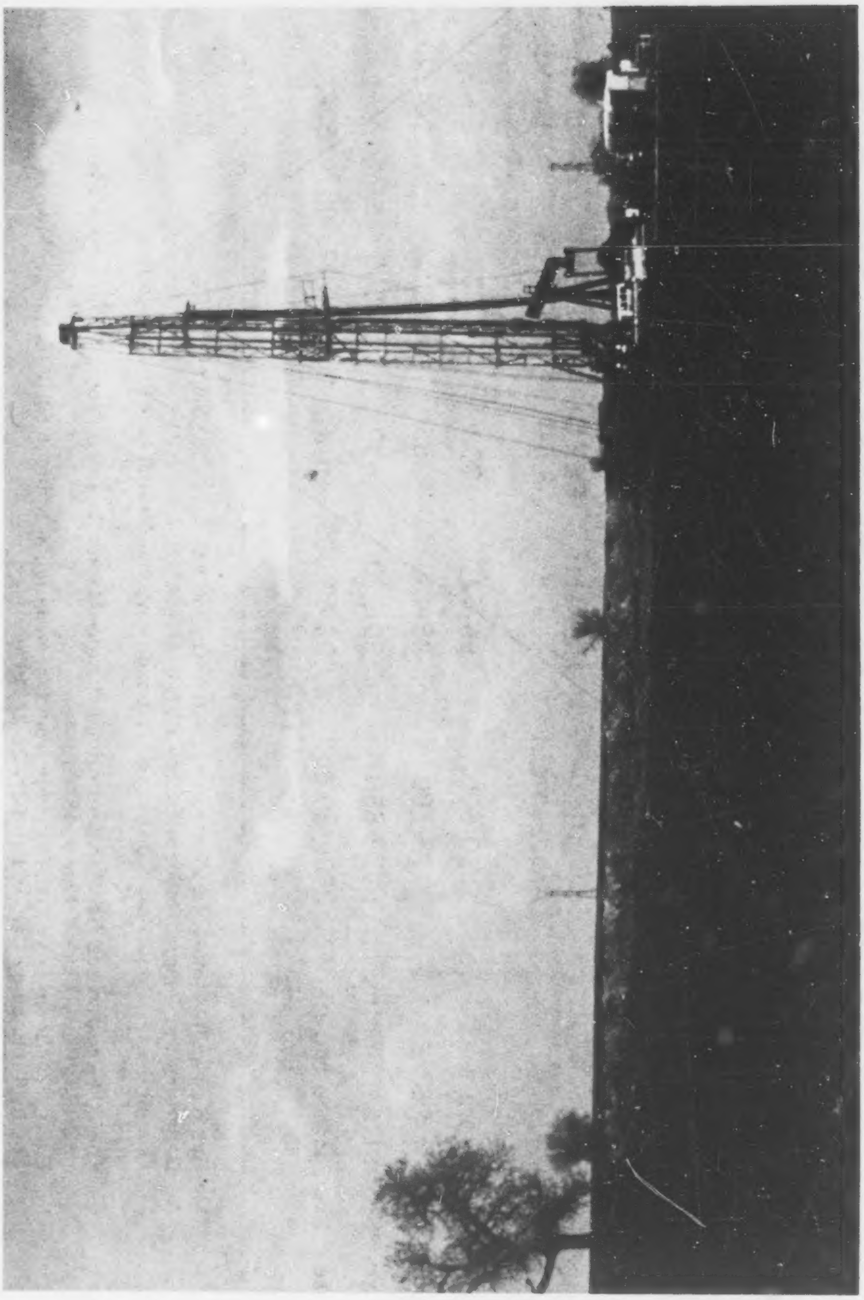

Launch
Escape
System
COMMAND MODULE
SERVICE MODULE
SERVICE PROPULSION SYSTEM
ENLARGED BELOW
Lunar Module
Instrument Unit
S-IVB
Third Stage
S-II
Second Stage
S-IC
First Stage
Five
F-1 Engines
Astronauts
Service Module
Engine Fuel Tanks
Fuel Cells
Liquid Oxygen and
Hydrogen Tanks


Project Gemini
Liquid Oxygen Control Console
Liquid Hydrogen Control Console
Oxygen Fill and Vent Lines
Hydrogen Fill and Vent Lines
White Room
Gemini Spacecraft
Launch Tower
Liquid Hydrogen Control Console
Liquid Oxygen Control Console
Liquid Hydrogen Service Unit
Terminal Boxes
Liquid Oxygen Service Unit


S.C. L N G CO







Estimates of Total U.S. Resources of Unconventional Natural Gas (TCF)

Resource	Range of Resource Estimates				
	GR1[1] Assessment	NEP-11[2]	FERC[3] 6/78	ERDA[4] MOPPS	DOE ET-VI
Western Tight Sands	50-600	50-420	793	600	50-320
Eastern Devonian Shale	75-700	25-400	285	600	10-520
Methane From Coal Seams	72-860	50-700	850	2500	16-500
Geopressured Zone Methane	3000-50,000	5,000-63,000	n/a	3,000-100,000	150-2,000

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1 Gas Research Institute. Gas Research Institute Digest. Vol. 2. No. @. March 1979.
2 Department of Energy. National Energy Plan-II. May. 1979.
3 Federal Energy Regulatory Commission. Nonconventional Natural Gas Resources Report DOE FERC-D010. June. 1978.
4 Energy Research and Development Administration. Market Oriented Program Planning Study (MOPPS) Review Draft. June 1. 1977.
5 Energy Technology VI. Gas Recovery from Unconventional Sources by DOE Morgantown Energy Technology Center. February 26-27. 1979.

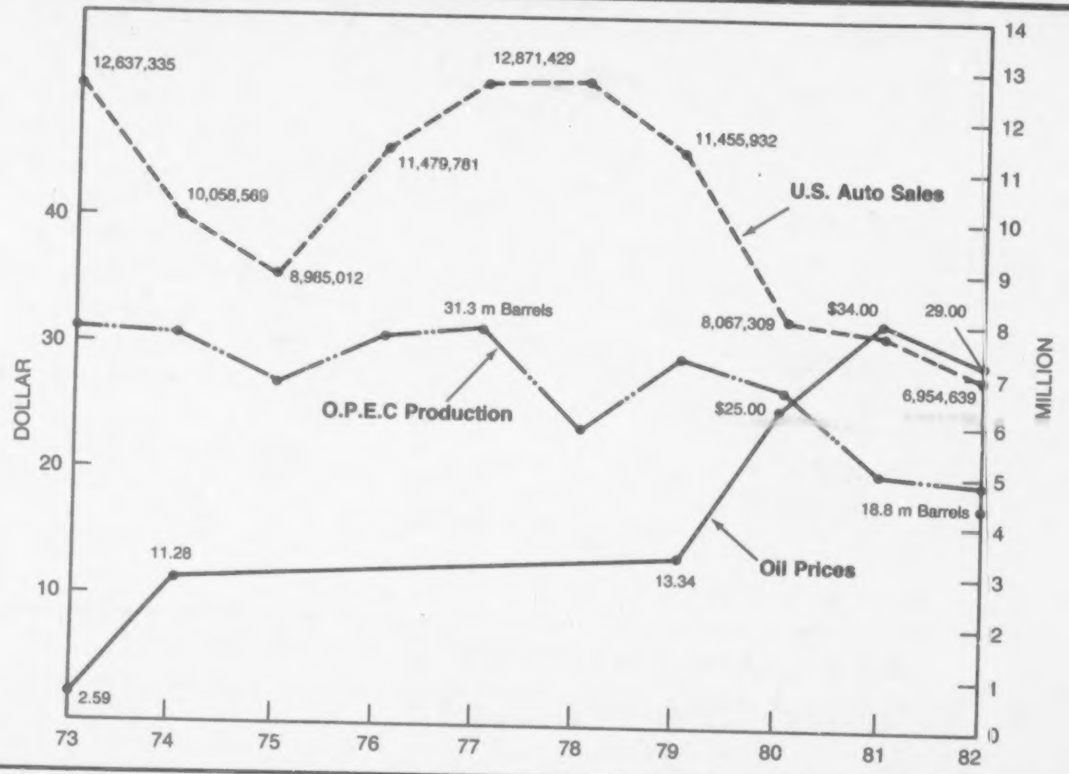
Comparison of LNG Operations Risk Assessment with Known Risks

Accident Type	Fatality Probability per Exposed Person per Year
Motor Vehicles	1 in 27,000
Falls in Public Places	1 in 240,000
Fires in Homes	1 in 260,000
Falls in Homes	1 in 460,000
Fires in Public Places	1 in 3,000,000
Air Transport	1 in 5,000,000
Poisoning by Gases	1 in 5,000,000
LNG Operations	1 in 10,000,000 to 1 in 100,000,000
Lightning	1 in 50,000,000

Sources:

1. Supply of Liquefied Natural Gas to the Northeast. (Upton, N.Y., National Center for Analysis of Energy Systems. Brookhaven National Laboratory for U.S. Energy Research and Development Administration. April. 1976). p. 68.
2. Accidents and Unscheduled Events Associated With Non-Nuclear Energy Resources and Technology. (Washington, D.C., U.S. Environmental Protection Agency. February 1977). p. 174. Figures shown for LNG were derived from assessments performed by Science Applications Inc. and El Paso Alaska Co. Range reflects different sites and methodologies.

Impact of Oil Prices on Automotive Sales and O.P.E.C. Production



Aircraft: Sundowner

Annual Operating Hours: 600

Hourly Fuel Consumption (Cruise): 10.4 Gallons

	Av-Gas	**LM**
Fuel Use: Per Day Gallons (600 hrs ÷ 262 days = 2.29 hrs/day)	23.8	23.8
Fuel Cost: Per Gallon	$2.05	$0.65
Per Hour	21.32	$6.76
Per Day	$48.81	$15.47
Fuel Use Per Year, Gallons	6240	6240
Fuel Cost Per Year	$12,792	$4,056
Annual Savings Per Aircraft	$8,736.00	
Conversion Cost	$15,000.00	
Simple Pay Back	1.7 Years	

Alternative Fuels Comparison

	Lbs. per Gallon	BTU Per Gallon	BTU Per Pound	Hot Surface Ignition Temperature	Octane	Density Pounds Per Ft^3	Price Nat. Avg. Jan. 82
Methane	3.53	83,700	21,500	1170°F	130	26.5	.55
Methanol	6.60	57,000	8,600	660°F	110	65.0	.81
Propane	4.86	91,500	19,700	750°F	110	36.5	.83
Hydrogen	0.6	30,000	51,600	800°F	120	4.3	4.00
Gasoline	6.8	120,000	19,000	680°F	89	50.0	1.28
AV-Gas	6.2	125,000	19,000	500°F	110	50.5	2.05
Jet A	6.5	125,000	18,600	500°F	40	50.5	1.78

Sundowner Engine Test Stand Results

Test Conditions	Av-Gas			LM		
RPM	2700	2450	2350	2650	2450	2350
Horsepower	136.4	101.5	88.7	125.1	99.8	90.6
Fuel Flow (LB/HR)	76.0	58.3	53.9	54.2	42.0	32.8
(Gallons)	12.3	9.4	8.7	15.3	11.8	9.2
S.F.C. (LB/HP/HR)	.557	.580	.608	.443	.421	.362
Horsepower (Standard day Conditions)	179.9	105.6	92.3	161.7	103.8	92.6

Aircraft:	TH-55		
Annual Operating Hours:	786		
Daily Operating Hours:	3.0		
		AV-Gas	**LM**
Fuel Use: Per Hour		13.0	14.9
Per Day		39.0	44.7
Fuel Cost: Per Hour		$20.80	$ 6.26
Per Day		$62.40	$18.77
Per Year		16,348.80	$4,918.79
Annual Savings: Per Aircraft		$11,430.01	
144 Aircraft		$1,645,921.40	
Conversion Cost (est)		$20,000 each	
Simple Payback		1.7 years	

Mr. **Glickman**. Thank you, Roy. I'm sure we are going to have many questions of you, but we'd like to get to our other witness, who is Harry Zeisloft, Experimental Aircraft Association. We appreciate your being here and why don't you go ahead.

Mr. **Zeisloft**. I appreciate the opportunity to tell you about what we have been doing, and we are certainly pleased with your concern that general aviation may be running out of gas.

Our present situation and the way we got there is a good place to start, and that is that we have two grades of aviation gas for personal aircraft, 100 low lead and 80 grade av-gas.

In the disruption of fuel supply systems in the early 1970's, the oil companies advised that they would like to get rid of 80 octane for obvious reasons. It's a very small product and it would be to the advantage of everyone if there were a single fuel. At that time there was a very large percentage of the fleet had 80 octane engines. And some tests were done, also at Embry-Riddle, that established that 100 octane fuel could be used but it had some serious problems. And there were changes made then to the rules. The lead levels of this 100 octane fuel reduced the problem magnitude in using that fuel in 80 octane engines. However, 100 low lead fuel still has two grams of lead per gallon compared to a half a gram which was in the fuel the engine was designed for. And this has led to some problems that the FAA issued an advisory circular, describing all the bad things that were going to happen if you were forced to use 100 low lead fuel in an 80 octane engine.

The feeling that existed at that time, which I find difficult to go along with, is that now we have told you all of these bad things that are going to happen, there is no degradation of safety. I feel that's a pretty head-in-sand attitude. If I'm flying an airplane that is likely to have spark plugs fouling and piston rings breaking, and you tell me all I have to do is inspect it every 25 hours to fly safely. When I'm flying over Kansas in the middle of the night and in a bank of clouds, I'm not sure I would really enjoy that.

So we felt there was a real problem in using 100 low lead av-gas in these engines, and we still do, and that there is a better fuel available, which is simply automobile gasoline. And in order to get off the ground on this, first we had to convince the FAA to withdraw their rule that they established in 1976, that they would not accept any applications to use automobile gasoline in airplanes. And after that was accomplished, then we faced the problem of the certification of this fuel.

There is some processes that are set up and in place for all aircraft builders and engine builders to certify their products as being airworthy. These are exactly the same procedures we had to go through to certify an aircraft using automobile gasoline.

It was also necessary at this time to establish for the FAA that there was some known dimension of automobile gasoline. In spite of the fact that we have 20 years backlog of data accumulated by the Department of Energy and the Department of Transportation, which pretty well defines the automobile gasoline on the market, it was felt that there was a need for a specification, so of course we used the standard specifications of the ASTM D-39, which are universally accepted as covering automobile gasoline.

So after we had that established, we simply followed the procedures outlined by the FAA advisory circular, that's advisory circular No. 20-24, that outlined some optional methods of approval. And this circular, by the way, was entitled, "Approvals of Alternate Fuels and Lubricants," and it defined a 500-hour flight test with defined power settings and various other conditions of flight to be handled in these programs.

So we went through this procedure with the Cessna 150 airplane, with a 100 horsepower engine, and of course before doing that, we did feel that we had feasibility established by many years of using automobile gasoline legally in amateur-built aircraft, which also incorporated in many cases the standard aircraft engine. And then, too, we used automobile gasoline exclusively in our *Spirit of St. Louis* replica and the Stinson that accompanied it throughout its tour and duplicated Lindberg's tour of its flight. And that gave us the exposure of automobile gasoline and a wide range of geographic locations, and in a wide range of ambient conditions. And we found, again, that it appeared to be more than satisfactory fuel for that aircraft.

So our actual testing, then, has accomplished, has included some FAA-conducted flight tests, and we have done the required cooling tests. We have done the restart testing, hot fuel testing, where the fuel must be heated to 110 in the tanks, and then a climb made to service ceiling, and detonating testing, not because we were concerned about the octane number, but simply to prove again that the octane rating was adequate for these engines. At the end of these tests, the engine was torn down and had an official FAA inspection, which was found to be satisfactory.

And in addition to the required testing by the FAA, we have done performance comparison tests, and because we were concerned along with others, about the validity of vapor lock testing using hot fuel, we also conducted a series of tests under high ambient conditions with the fuel refrigerated from the time it left the Amoco Laboratories until we got it onto the airplane, so we also tested with other specific fuel, where we had Amoco compound for us a special fuel at higher RVP's than any fuel in the country, so we feel that that was a pretty conservative investigation.

And then also in order to convince ourselves, as well as the FAA we selected a fuel from a random—from random sources throughout the country, and we deliberately tried to go to mom and pop stations, grocery stores, out-of-the-way places where we felt that there was a chance for finding fuel that may not be up to snuff from an engineering standpoint. Unfortunately, we did not encounter any of those kinds of fuels. Everything that we bought, put into the airplane, turned out to be fuel that was within the specifications.

Incidentally, every different load of fuel that we put in the airplane, we had samples sent down to Amoco Laboratories, again where they gave us complete analysis of the fuel. In addition to doing this with the regular specification fuel, we had some discussions with the FAA Technical Center at Atlantic City and the University of Michigan, who was doing some contract work for them on the subject. The University of Michigan defined two fuels that represented two extremes, that the oil industry felt would be the most disadvantageous fuel for use in an aircraft engine. And we did, under contract with the University of Michigan, fly these fuels also, and again from an engineering standpoint, unfortunately we didn't encounter any problems that we could define or identify, and the airplane operated completely satisfactory through our complete range of testing.

These fuels included a 100-percent scat crack fuel with a 15 RVP, which is a very high volatile fuel, which was expected to give us vapor locking and icing problems, and possibly detonation. The other fuel was a heavy fuel, a catalytic reformate. Both of these had 5-percent oxygenated materials, and this fuel was only 9-to-10 RVP and was expected to give us some maldistribution problems and detonation. And, of course, during the flight tests we had both. We have our airplane very thoroughly instrumented and we could find no particular problems using these extreme examples of automobile gasoline.

So we did complete our application to the FAA for approval for this aircraft. They reviewed all our data and agreed that this was a perfectly airworthy aircraft. There were no changes required in the engine, no changes required in the airframe and no changes required in the operation of the airplane.

So, based on that success, we advanced to the Cessna 182 aircraft and we continued another 500-hour test. In this case the engine was the largest that exists that is rated on 80-octane fuel.

And please remember that up to this time we are strictly talking about 80 octane fuel substitution. We do feel that in the future we can look at the possible substitution for 100 octane, but that is, of course, we recognize, another area which will require considerable technical development and additional information.

The areas of concern that we had with these fuels were, first of all, exactly the same concern as everyone has with aviation gasoline. And, again, the FAA has issued an advisory circular which is an exceptionally well written document, that outlines potential hazards of contamination of fuel. That includes both water and solids, but we were concerned primarily with water. And it turns out that the techniques that exist for handling contamination in aviation fuel are exactly those that are needed to insure that uncontaminated fuel gets into aircraft, regardless of whether it is aviation fuel or automobile gasoline.

But then in our second airplane, the Cessna 182, which is a four-place personal aircraft, the NTSB reports on the accident rates indicate that it was one of the number of airplanes that was involved in accidents at a higher level of frequency than others, due to water in the fuel. Now, bear in mind that all this accident data has been accumulated with aviation gasoline. It will be no different with automobile gasoline. Water enters the fuel system, and by condensation in the tanks in some cases bladder tanks, make it very difficult to remove entrained water. And there, I believe, is the source of the problem in those aircraft. We are quite concerned about that because there is nothing different about automobile gasoline that would lead you to expect it will be superior in performance in that regard.

We have also initiated some programs in our research department that are utilizing automotive technology that now exists in sensing the fact that there is water in the fuel, and also in utilizing automotive technology, straining water out of the fuel so that it does not get into the fuel, the engine system, and cause an accident.

Our conclusions were that these 80-octane engines certainly can operate satisfactorily on automobile specification fuel. When we look at all engines, we find the critical factors, of course, are the engine octane compatibility and there is no question about it, that if an engine has a high enough compression ratio that it requires a given octane level fuel, and you must provide that level or suffer the consequences of detonation.

Another critical factor, too, is the engine aircraft fuel system design, which must be able to handle the volatility levels of the fuel that you supply, and also, the third factor, of course, is the simple materials compatibility problem.

In the way of recommendations, we have a number of things that we think would be worthwhile for NASA to look into in terms of developing new information, particularly developing new design engineering information, which I think in view of the potential market will be a tremendous burden on industry to attempt to do on their own, and yet it is really vital to our continued efforts to build airplanes and have fuel available to fly with.

We need information on the octane compatibility situation with respect to the engine and the fuel.

We need much more information on the volatility characteristics of fuel, particularly with respect to design parameters so that fuel systems can be designed the first time around to handle any given defined volatility level.

At the present time, of course, most of those designs are empirical. You do it this way because you know it works, and you attempt to increase the range and volatility you cut and try to put in a bigger line, you eliminate the bends and so on. We need design information in that area.

Then, too, I think the FAA should take an initiative, and I believe that in view of the circumstances, that the FAA should require any new aircraft design to be able to handle any readily available gasoline, and that means a requirement that would cover the volatility levels that are currently existing in automobile gasoline, and which do not appear to be in danger of going up in the near future, or foreseeable future.

I think the FAA also should correct the numerous publications that are in the field at the present time which provide erroneous information, in light of this new knowledge, which generally say, "Warning, do not ever use automobile gasoline in an aircraft." That was a function of ignorance. We have gained new information now on that situation and it should be corrected immediately.

There is a question in my mind as to whether or not the authority here, or the approval of 100 low-lead aviation gasoline to be used in 80 octane engines perhaps should be withdrawn, in view of the recognized problems with that fuel in these older engines. Simply because the fuel, because it says "aviation," by no means means that is the best fuel for that engine, and I am sure that if things hadn't been in such a state of confusion in the seventies, with the shock of finding out our dependency on foreign oil, I am sure that people would have taken a broader look at potential alternates at that time, because there is no question in my mind that a review of the specifications of both aviation gas and auto gas show an auto is completely compatible with these lower compression engines and is an immediately available substitute right now.

Now, there are some impacts that we should talk about, too, regarding this substitution which can be made in the very near future, and that is, the economic impact on the aircraft owner is immediate and dramatic. In a Cessna 150 he can expect to reduce his flying costs by something in the order of $5 or $6 an hour, depending on the price of fuel. But don't misunderstand that, the savings is only in the price of fuel. In this particular instance, the savings is largely due to the fact that the auto fuel does not require the added maintenance of 100 low lead av-gas, which is his only other alternative, requires, so that the total effects which were documented by the Embry-Riddle tests in 1976 and 1977.

At that time, they found the simple substitution of 100 low lead for 80 octane cost them $2.57 an hour in operating costs, just for maintenance only. So when you extrapolate that to the cost savings that are represented by this higher horsepower engine, in the Cessna 183 we find that you could certainly estimate about $12 an hour direct savings in operating costs in that airplane right now.

Now, if you take an average figure and look at the average percentage of the fleet which still uses 80 octane engines, we are talking about a savings nationally annually in the range of $300 million.

Mr. GLICKMAN. The savings between the 100 low lead av-gas and the automobile gasoline?

Mr. ZEISLOFT. That is right.

Mr. GLICKMAN. OK.

Mr. ZEISLOFT. So that is available savings immediately, so we think it warrants your serious consideration.

[The prepared statement of Mr. Zeisloft follows:]

Aviation FOUNDATION
DEDICATED TO THE EDUCATION, HISTORY AND DEVELOPMENT OF AVIATION

EAA AVIATION FOUNDATION

FLIGHT RESEARCH PROGRAM

By

Harry C. Zeisloft
EAA Technical Director

AN ALTERNATE FUEL FOR GENERAL AVIATION

Summary

The Experimental Aircraft Association, a group dedicated to promoting personal participation in all phases of aviation, has completed DOT/FAA official flight tests leading to the approval of the use of automobile gasoline in six (6) different personal aircraft which exist in large numbers in the civil aircraft fleet. Long-range plans are to continue development and proof testing until autogas is approved in all aircraft. Short-term planning is directed to aircraft modification, if necessary, and approval of the use of unleaded regular autogas in all aircraft which were initially approved to use 80 grade avgas. Unleaded autogas is an immediately viable alternate fuel for 80 grade avgas. A potential exists for an annual savings in operating costs for aircraft owners of $300,000,000.

Harry C. Zeisloft
August 25, 1983

11311 W. FOREST HOME AVE. FRANKLIN, WISCONSIN 53132 — BOX 469, HALES CORNERS, WISCONSIN 53130 — PH. 414/425-4860

AN ALTERNATE FUEL FOR GENERAL AVIATION

Introduction

In the mid-1970's, personal aviation received its first indication of its total dependence upon a single product . . . aviation gasoline. Aviation gasoline is an insignificant quantity in the energy spectrum in the United States. It amounts to only 4/10 of one percent of the total gasoline consumed in the United States; and is further subdivided into two grades: 80 grade avgas and 100LL grade avgas. That we have any aviation gas at all today is a tribute to the loyalty of a few major gasoline suppliers to personal aviation. It is appropriate, then, that steps be taken to find a substitute which will be both readily available and more economical than the specialty product available today.

It is apparent that unleaded regular automobile gasoline has all of the attributes and qualities to fill the need for personal aviation's requirements; and, with today's technical expertise, need not have any functional nor safety compromises.

The Experimental Aircraft Association's members, in years of use, have already established the feasibility of this substitution through the legal use of autogas in amateur-built aircraft certified in the experimental category.

Additional feasibility had already been established in 1977 by EAA's "Spirit of St. Louis" replica and the accompanying Stinson which duplicated Lindbergh's 1927 tour around the United States. During this tour, they each accumulated approximately 700 hours of flying entirely on automobile gasoline in a wide geographical area and under varied atmospheric conditions. Other EAA aircraft legally operated on autogas with no ill effects.

In 1978, Paul Poberezny, President and Founder of the Experimental Aircraft Association and EAA Aviation Foundation, directed that a program be initiated aimed at legalizing the use of automobile gasoline in all aircraft where it can be an immediately available satisfactory substitute.

With this background, the EAA submitted a request to the DOT/Federal Aviation Administration Great Lakes Regional Office to conduct a flight test program in accordance with Federal Air Regulations for the approval of automobile gasoline in a specific aircraft. We were then directed to work with the DOT/FAA engineering office in Washington with the result that the FAA withdrew the 1976 ban on accepting applications for the approval of the use of autogas in aircraft.

An autogas flight test program was established to determine the engineering characteristics of automobile gasoline in flight to evaluate the effects of the higher volatility fuel permitted in the automobile gasoline specs and to find technical solutions for problems which might be encountered. Because unleaded autogas was judged to be the most available gasoline in the foreseeable future and because its octane rating exceeded that of 80 grade aviation gasoline, it was selected as the alternate fuel.

EAA Autogas Program

The technical rationale included a detailed comparison of the specification for automobile gasoline (ASTM D-439) with the generally accepted specification for aviation gasoline (ASTM D-910). The result of this comparison shows that the only technical difference of any significance was the difference in fuel volatility. This is primarily a matter of the design of the aircraft fuel delivery system and not of significant impact in the operation of the engine itself. For this reason, we chose to test a high-wing aircraft first having a simple gravity feed fuel system least influenced by high volatility fuel.

The flight test program was then established to investigate the use of automobile gasoline in simple gravity-feed aircraft systems and to approve its use in as many of these aircraft as possible. We limited our investigation initially to the substitution of unleaded regular automobile gasoline for 80 grade avgas. This is because any automobile gasoline in the country has a higher aviation octane rating than the 80 octane required for these engines. We will continue our work until all Continental and Lycoming engines capable of burning 80 octane fuel are investigated and approved. We planned to work for the approval first of high-wing, simple gravity-feed fuel sytesms, and then progress into the more complicated aircraft with engine-mounted fuel pumps and complex fuel systems represented by low-wing and multi-engine aircraft.

We flew a total of 630 hours in a Cessna 150 aircraft. The aircraft was fully instrumented, and a considerable amount of engineering test data has been accumulated. All DOT/FAA tests which were required for the initial certification of this aircraft powerplant and fuel combination, were accomplished again to the satisfaction of the FAA; and approvals were received for both the aircraft and the Continental 0-200 engine.

EAA Flight Testing

At the present time, the Experimental Aircraft Association has accumulated more than 1,300 hours of engineering flight tests with fully instrumented aircraft. This testing includes official FAA conducted flight tests involved in the approvals for the Cessna 150 and Cessna 182 aircraft to use automobile fuels. It also includes flight testing under contract for the University of Michigan where two special fuels were compounded which were intended to represent the worst characteristics of fuels which could be expected in automobile gasoline when used for aircraft. We have also conducted test work on special fuels provided by Imperial Oil Limited for use in testing requested by the Airworthiness Branch of Transport Canada in Ottawa.

Test flying has included every type of powerplant test specified by the Federal Air Regulations as well as additional testing judged by the EAA to be desirable. These tests have included detonation testing, engine cooling tests, air restarting tests, aircraft climb performance testing and hot fuel testing. The additional tests included by the EAA cover heat soak periods during touch-and-go operations at full power and vapor lock testing with special high volatility fuel both heated, in accordance with FAA regulations, and refrigerated, in accordance with the latest thinking by oil industry engineers.

The instrumentation packages in use are among the most sophisticated available for the purpose today. They include digital data readouts; a flexible programmer which can be programmed in flight to sample data at various intervals and in various combinations; and a recorder to provide permanent records of data taken. We have been supported in this area by the John Fluke Instrument Company's equipment.

We have had excellent industry cooperation in technical matters; and the companies involved in building the aircraft, engines, and instruments have been most helpful in providing technical advice and suggestions.

The AMOCO Research Laboratories have provided special fuels with volatility exceeding the ASTM specs for use in vapor lock testing. They also provide technical assistance and laboratory support in the analysis of the fuels used during EAA's test program.

Cessna 182 Program

Next, EAA proposed and conducted an official DOT/FAA flight test to demonstrate compliance with the Federal Air Regulations. The flight test involved more than 500 hours of similar testing on the four-seat Cessna 182 aircraft with a 230 horsepower Continental engine. Engineering data was also gathered and submitted to the DOT/FAA who again concluded that automobile gasoline was a satisfactory fuel for this aircraft.

At the present time, EAA has received approvals for the use of unleaded regular automobile gasoline in the following aircraft: Cessna 120, Cessna 140, Cessna 140A, Cessna 150, Cessna 180, and Cessna 182. Aircraft engine approvals for the use of autogas range from 40 h.p. to 230 h.p.

We are in the process of working toward the approval of other high-wing aircraft such as Cessna 170's, 172's and other makes and models of high-wing personal aircraft.

We are also initiating a request to conduct a test program for low-wing aircraft such as the Beech Skipper and the Piper Cherokee series using Lycoming engines. We expect to begin flying in the near future.

These approvals are being made available to all aircraft owners at a nominal cost, and funds generated are being used to continue this program.

Economic Impact - Aircraft Owners

The economic benefit to the individual aircraft owner is immediate and dramatic. In 1977, the FAA and members of the aviation industry co-operated in an evaluation at the Embry-Riddle Aeronautical University that compared the use of the recommended 100LL avgas in place of the 80 octane avgas which, at that time, was not available. The airplane owner was found to have an added cost of $2.54 per operating hour. Today, adding an estimated savings of $.50 to $1.00 per gallon on the purchase price for unleaded regular autogas, we can axpect a further savings of up to $5.00 per hour. Thus, in 1983 there is a total operating cost savings of approximately $8.53 per hour.

In the case of the Cessna 182, these savings can be extrapolated to more than $12.00 per hour of operation. This represents a potential of more than $300,000,000 annually for all aircraft owners operating piston-engine airplanes.

Economic Impact - Fixed Base Operators

Fixed Base Operators benefit by increased traffic generated from the reduced cost of flying. People fly more, rent more airplanes, buy more supplies and buy more service if the cost per hour is lower. FBO's will also have the option to sell gasoline in the automobile as well as the aircraft market. When petroleum supplies become short, autogas again will be the most available fuel. The elimination of the uncertainties in the supply of aviation fuel will insure that an FBO can continue in business. Fixed Base Operators will also become independent of the restrictions in quantity, pricing, and cash outlays that they are now exposed to with aviation gasoline. They also can benefit by the participation in a broader and more competitive market. Fuel sold on the airport site can justify a few cents a gallon more for the convenience of direct fueling for an aircraft owner/operator.

Economic Impact - Fuel Industry

There is also an advantage to the fuel industry in the ultimate elimination of what has turned out to be a nuisance product line . . . aviation gasoline. At the 1981 SAE General Aviation meeting in Wichita, it was stated by the Chairman of the Board of a major aircraft company, "In the 1990's, there will be no aviation gasoline." We agree. It also is self-evident that GAMA aircraft manufacturers can provide their customers with a more usable product, a more economical product, and initiate an emergence from the doldrums that the personal aircraft business is currently experiencing.

Economic Impact - Worldwide

The impact of these approvals in world aviation extend to Great Britain and other European countries, New Zealand and Australia. It is watched with increasing concern and hopeful anticipation by the many humanitarian and religious groups utilizing aircraft in far-flung outposts where the insistence upon aviation gasoline is a major hindrance to effective aircraft utilization.

The Experimental Aircraft Association has been in contact with agencies in Canada, Great Britain, New Zealand and Australia, all working and gathering data to demonstrate that automobile gasoline is, in fact, a satisfactory fuel for aircraft use. Great Britain approved the use of automobile gasoline in a wide range of aircraft as a result of work done by the British Gliding Association and influenced by engineering data exchanged with the Experimental Aircraft Association.

Future Plans

EAA's future plans include working toward approval of the use of automobile gasoline in all 80 octane Teledyne Continental and Lycoming aircraft engines. It anticipates the approval of these engines and automobile fuel in all aircraft. We understand that more complex aircraft systems may require physical changes in the fuel system itself which has not been the case in the aircraft which have been approved at this time.

We also anticipate initiating work to determine the feasibility of the substitution of automobile gasoline for 100 octane avgas, and fully understand the technical nature of this problem. However, there is a precedent established in the use of lower grade fuels in military aircraft when necessity under combat conditions make this operation imperative.

Recommendations

1. NASA should undertake an aggressive program to determine the limits of detonation in high compression aircraft engines both normally aspirated and supercharged. There is a need for reliable design information to better establish the relationship between the anti-knock requirements of a fuel and the compression ratio and power output level of piston engines. Currently, available engines requiring 100 octane fuel should be investigated in terms of determining actual limiting of octane requirements. Accompanying research is required in gasoline development permitting achievement of these octane levels with a more economical and readily available fuel.

2. NASA should undertake a program to establish design parameters for the use in current and future piston engine aircraft to permit the sound engineering design of fuel supply systems utilizing highly volatile fuel and the anticipated further development of oxygenated gasolines.

3. NASA should initiate a program to develop the necessary engineering design parameters to insure that the design of aircraft fuel supply systems will incorporate materials which will be compatible with generally available future fuels, in particular automobile gasoline and gasohol.

4. The FAA should include, as a requirement for the certification of any new piston engine aircraft, the capability of operating on generally available fuels such as automobile gasoline and gasohol. It is generally recognized that the illegal use of automobile gasoline is widespread both in this country and in other areas throughout the world.

5. FAA near-term research activities should be directed toward the establishment of an "aviation grade" automobile gasoline based on conformance to ASTM D-439.

6. Aircraft manufacturers have access to the technical knowledge and engineering capabilities necessary to design personal type aircraft with fuel systems capable of safely handling high volatility gasoline throughout all conditions of flight. Any new production, piston engine aircraft should include this capability.

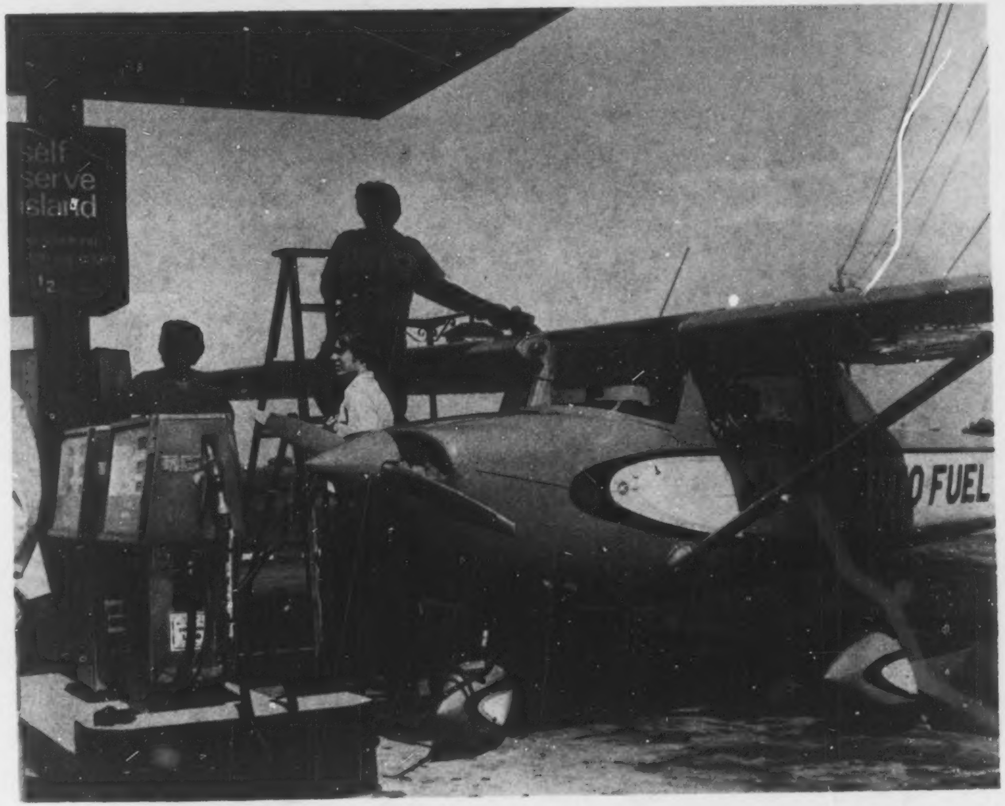
# # #

APPENDIX

CONGRESSIONAL HEARINGS

"An Alternate Fuel For General Aviation"

1. EAA Report (AFR-81-1) - Flight Test, Cessna 150 on Autogas
2. EAA Report (AFR-83-2) - Flight Test, Cessna 182 on Autogas
3. EAA Report (AFR-83-1) - Flight Test, University of Michigan Special Fuel
4. EAA Report (AFR 83-3) - Flight Test, Canadian MOT Special Fuel
5. SAE Report (SAE No. 830706 - April, 1983) - Autogas Flight Test In A Cessna 150 Airplane
6. Embry Riddle Aeronautical University Report - "Qualification Testing of TCP Treated 100LL Fuel" By The Wallace Research Center, 1977
7. DOT/FAA Report - "The Impact of Petroleum, Synthetic, and Cryogenic Fuels on Civil Aviation". By Charles L. Blake Available through NTIS Report No. DOT/FAA/EM 82/29.
8. DOE/DOT Report - "Motor Gasolines" By Ella M. Shelton DOE/BETC/PPS - 76 - 1 through 82.
9. NTSB Tab Runs
10. FAA Advisory Circular No. AC 91-33 - "Use of Alternate Grades of Aviation Gasoline for Grade 80/87"
11. Fuel Specifications
    - a.) Unleaded Autogas, American Society for Testing Materials, ASTM D-439
    - b.) University of Michigan Special Test Fuel
    - c.) Canadian MOT Autogas with MMT
12. G.M. Report - FL-580 -"U.S. Automotive Fuels - Status and Prospects" By Nick Gallapoulus


self
serve
island
O FUEL

FILL 'ER UP!

The EAA Aviation Foundation's auto fuel testbed Cessna 150 refuels at an AMOCO gas station.

AUTO-FUEL-TEST
APPROVED
Amoco
67

AUTO FUEL APPROVED FOR USE IN AIRCRAFT

Administrator J. Lynn Helms discusses FAA's approval for auto fuel in the Cessna 150 with EAA President, Paul H. Poberezny.

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830706

Autogas Flight Test in a Cessna 150 Airplane

Harry Zeisloft
Experimental Aircraft Association

Business Aircraft Meeting & Exposition
Wichita, Kansas
April 12-15, 1983

830706

Autogas Flight Test in a Cessna 150 Airplane

Harry Zeisloft
Experimental Aircraft Association

ABSTRACT

Because of the availability and cost problems in supplying 80 grade aviation gas to the users, and because of the high maintenance costs and lowered reliability when using 100LL aviation gasoline in 80 octane, aircraft engines, flight tests were conducted to determine airworthiness of the aircraft and compliance with Federal Air Regulations when using automobile gasoline.

On the basis of these tests, FAA approval has been given for the use of unleaded regular automobile gasoline for all Cessna 150 airplanes powered with Teledyne Continental Motors 100 hp. engines. No changes were required to the airframe, engine or operation of the aircraft.

Of all the gasoline used in the United States, approximately 4/10 of 1% is aviation gasoline.[1] It has been distributed in as many as 4 different grades, 80, 91, 100 and 130. At the present time, the only aviation gasoline available in some places is 80 grade and 100LL. In most places only 100LL aviation gasoline is available, it is thus also used in small engines requiring only 80 octane fuel. There are many adverse effects encountered.[2] However, review of the specification of automobile gasoline, shows that there is no technical reason barring its use in aircraft engines requiring 80 octane fuel, and that its lead content is much more compatible with these engines than that of 100LL avgas. None of the bad effects of excessive lead outlined in FAA Advisory Circular 91-33 are applicable to lead free automobile gasoline. Since automobile gasoline is permitted to have a higher volatility, the aircraft fuel systems must be capable of handling it under adverse conditions.

The properties of automobile gasoline sold through service stations in the United States are reported in accordance with an agreement between the American Petroleum Instite and the Bartlesville Energy Technology Center of the United States Department of Energy.[3] This report presents analytical data on samples which are collected and analyzed twice a year and have been published from 1959 to the present time. This provides a factual data base on the actual composition and make-up of automobile gasoline that is being marketed throughout the United States today. This date indicates that fuel supplied throughout the United States generally conforms to ASTM D-439 specification requirements. The latest data, Winter 1981-82 shows the lowest average value in any region is 82.2 MON. It also shows a trend of reid vapor pressure below 13 psi. This data provides reasonable encouragement to consider automobile gasoline as a high quality substitute for 80 grade aviation gasoline.

The Experimental Aircraft Association therefore initiated feasibility testing using automobile gasoline in aircraft in the early 1970's. It appeared obvious that the quality of present day automobile gasoline deserved consideration when seeking an alternate fuel for personal aircraft. It offers lower cost to purchase; results in lower maintenance costs than when using 100LL avgas; it is immediately available throughout the country. In 1979, a formal engineering program was undertaken to flight test a Cessna 150 aircraft to examine the airworthiness of this airplane using unleaded autogas

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under adverse conditions. In August 1982, this program resulted in the FAA approval of the use of automobile gasoline in all Cessna 150 aircraft, and the grant to the EAA of Supplemental Type Certificates for the engine and for the airframe.

PROGRAM OBJECTIVES

The objectives of this program were to determine if the most readily available gasoline on the market, which was considered to be unleaded regular automobile gasoline per ASTM D-439 specification, would provide satisfactory function and performance in the Cessna 150 aircraft with a Teledyne Continental Motors Model 0-200 aircraft engine. If problems were encountered, solutions would be sought and an official FAA test program would then be undertaken to show compliance with the Federal Air Regulations and to establish that the airworthiness of the aircraft would not be affected by this substitution of fuels.[7]

CONCLUSIONS

1. This aircraft using automobile gasoline fully meets the Federal Aviation Administration Airworthiness requirements and was demonstrated to comply with Federal Air Regulations required for aircraft and engine type approval.
2. Function and performance were satisfactory in all respects.
3. No physical changes in the engine are required.
4. No physical changes in the airframe are required.
5. No change in operating procedures are required.

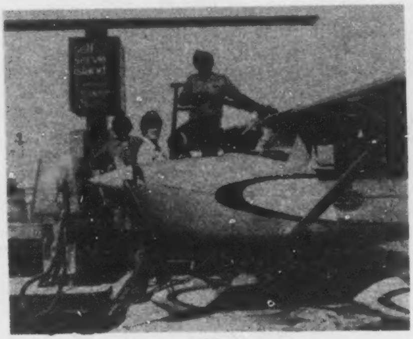


FIG. 1
EAA TEST AIRPLANE AT AN AUTO SERVICE STATION!

TEST AIRPLANE

Cessna 150H, 1968 N23107

Serial No. 15068729

Engine: TCM 0-200 A   Type Certificate E-252-8

Serial No. 68651-8-A

Total hours at start of test - airframe - 3774 hours

Hours since major overhaul on engine; at start of test - 365 hours

INSTRUMENTATION

Fluke Model 2190 Digital Thermometer (0.1° F precision)
(see appendix p. 4)

Fluke Model 2300 Scanner, 20 Channel
(see appendix p. 4)

Fluke Model 2030 Digital Printer
(see appendix p. 4)

Thermocouples - Type K

Fuel Pressure Gage 0-25 psi

FIG. 2

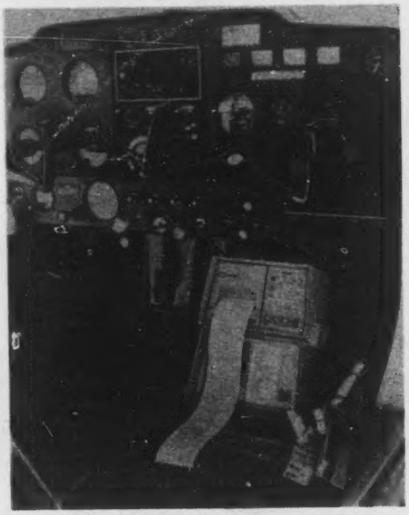


FIG. 3
DIGITAL THERMOMETER, PROGRAMMER AND DATA PRINTER IN EAA AUTO FUEL TEST AIRPLANE

It should be noted that compliance with the Federal Aviation Administration regulations require that anyone using automobile gasoline as approved in this airplane model series must incorporate Supplemental Type Certificates and must comply with their requirements.

DISCUSSION

A. Test Airplane and Instrumentation.
The test airplane is shown in figure 1 and described in figure 2. Figure 3 shows the Fluke data acquisition system installed. The instrumentation (See figure 2) consisted of a digital thermometer, a printer, and a data programmer capable of handling 20 channels of input. The fuel

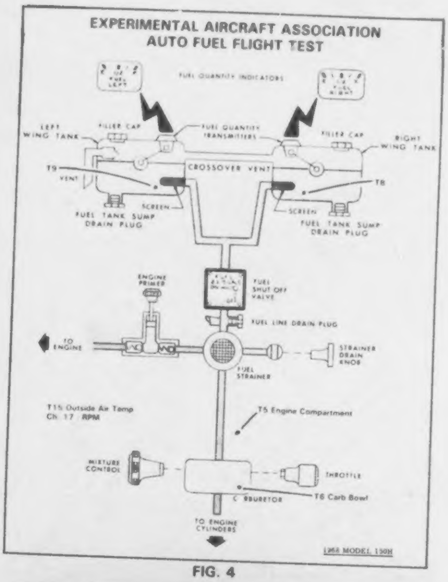

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST
FUEL QUANTITY INDICATORS
FUEL LEFT
FUEL RIGHT
LEFT WING TANK
FILLER CAP
FUEL QUANTITY TRANSMITTERS
FILLER CAP
RIGHT WING TANK
T9
VENT
CROSSOVER VENT
T8
SCREEN
FUEL TANK SUMP DRAIN PLUG
SCREEN
FUEL TANK SUMP DRAIN PLUG
ENGINE PRIMER
FUEL SHUT OFF VALVE
FUEL LINE DRAIN PLUG
TO ENGINE
STRAINER DRAIN KNOB
FUEL STRAINER
T15 Outside Air Temp
Ch. 17 RPM
T5 Engine Compartment
MIXTURE CONTROL
THROTTLE
CARBURETOR
T6 Carb Bowl
TO ENGINE CYLINDERS
1968 MODEL 150H

FIG. 4

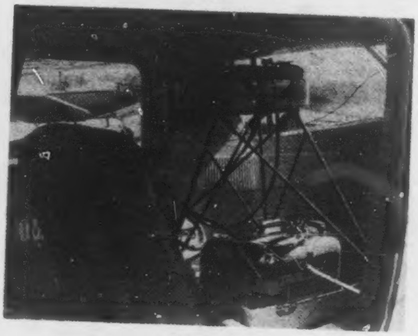
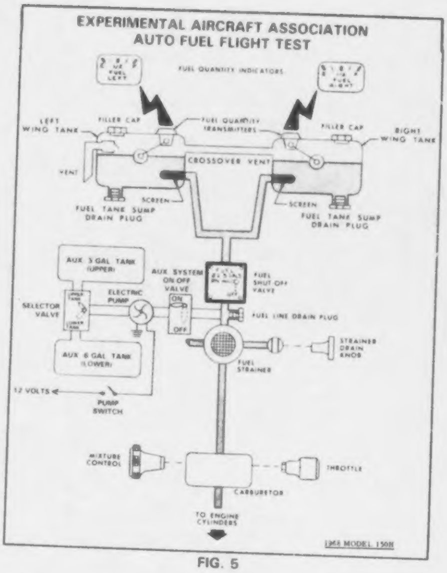


FIG. 6

AUXILIARY FUEL TANK INSTALLATION BEHIND SEATS IN EAA CESSNA 150


EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST
FUEL QUANTITY INDICATORS
FUEL LEFT
FUEL RIGHT
LEFT WING TANK
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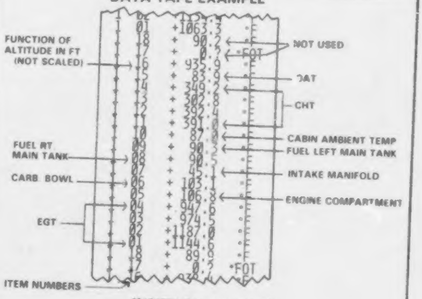
FUEL QUANTITY TRANSMITTERS
FILLER CAP
RIGHT WING TANK
VENT
CROSSOVER VENT
SCREEN
FUEL TANK SUMP DRAIN PLUG
SCREEN
FUEL TANK SUMP DRAIN PLUG
AUX 5 GAL TANK (UPPER)
AUX SYSTEM ON OFF VALVE
ON
OFF
FUEL SHUT OFF VALVE
SELECTOR VALVE
UPPER TANK
LOWER TANK
ELECTRIC PUMP
FUEL LINE DRAIN PLUG
STRAINER DRAIN KNOB
AUX 6 GAL TANK (LOWER)
FUEL STRAINER
12 VOLTS
PUMP SWITCH
MIXTURE CONTROL
THROTTLE
CARBURETOR
TO ENGINE CYLINDERS
1968 MODEL 150H

FIG. 5


DATA TAPE EXAMPLE
FUNCTION OF ALTITUDE IN FT (NOT SCALED)
NOT USED
OAT
CHT
CABIN AMBIENT TEMP
FUEL LEFT MAIN TANK
FUEL RT MAIN TANK
INTAKE MANIFOLD
CARB. BOWL
ENGINE COMPARTMENT
EGT
ITEM NUMBERS
01 +1063.3
18 + 90.2
17 + 0.2 FOT
16 + 935.9
15 + 83.9
14 + 349.2
13 + 302.8
12 + 392.4
11 + 391.0
10 + 87.0
09 + 90.3
08 + 90.5
07 + 45.1
06 + 103.1
05 + 106.8
04 + 947.6
03 + 974.5
02 +1187.0
01 +1144.6
18 + 89.9
17 + 0.3 FOT

INSTRUMENTATION

Instrumentation includes type K thermocouples, a digital readout and a programmed strip chart printout.

Active Channels Are:

1. EGT Cyl. 1
2. EGT Cyl. 2
3. EGT Cyl. 3
4. EGT Cyl. 4
5. Engine Compartment
6. Carburetor Bowl
7. Intake Manifold Spider
8. Right Fuel Tank
9. Left Fuel Tank
10. Cabin Ambient Temp
11. Cyl. Head Temp., Cyl. 1
12. CHT Cyl. 2
13. CHT Cyl. 3
14. CHT Cyl. 4
15. Outside Air Temp
16. Indicated Altitude

FIG. 7

system, figure 4, is a simple gravity feed system with two interconnected tanks, one in each wing root, with a fuel on-off valve, located in the cabin. The test installation of the auxiliary fuel tanks is shown in Figure 6. The schematic is shown in Figure 5. Figure 7 shows a sample tape and identifies the instrumentation components.

B. Vapor Lock.

The most recent prior work done on the study of vapor lock and its influence on aircraft design was in 1950 and is presented in SAE Paper 541 authored by Mr. Lock York, Al Hundere and, R.A. Coit.[4,5] They outlined recommendations that are still valid for fuel system design with regard to vapor lock. The Cessna 150 aircraft follows these guidelines and is one of the simplest and most straight forward fuel systems flying. The Cessna highwing personal aircraft series 120, 140, 170, 172, 180, 182, 185, and the like, have similar simple gravity feed systems, and can be expected to have fuel systems performance characteristics similar to that of the Cessna 150 airplane.

Specific efforts were made to induce vapor lock by flying with high temperature fuels and fuels with high reid vapor pressures (RVP). Exhaust gas temperature probes were installed in each exhaust stack and were used as an early warning for the onset of vapor lock.

While building operating time, 1700 touch and go take off and landings were completed in ambient conditions from mid-summer to mid-winter. During high temperature ambients, in order to aggravate the vapor lock possibility, the routine was to make 5 or 6 take off and landings and taxi to the ramp and shut down the engine. The temp. probe in the engine compartment showed when the temperature built up to a peak. The engine was then restarted and the airplane immediately taxied out for additional take off and landings. Under these conditions an extreme temperature reading of 135°F was recorded in the carburetor bowl. It was observed that

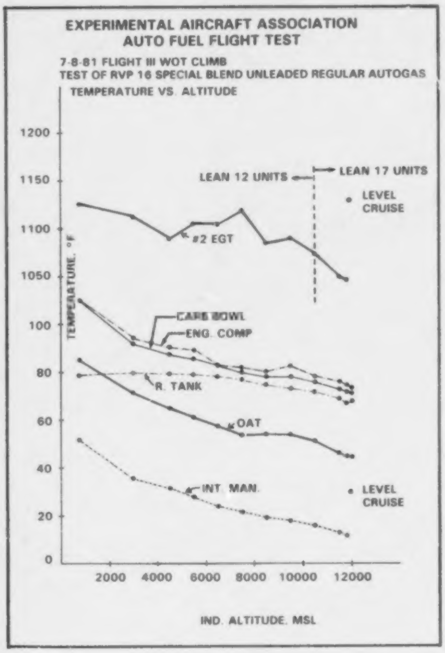


FIG. 8

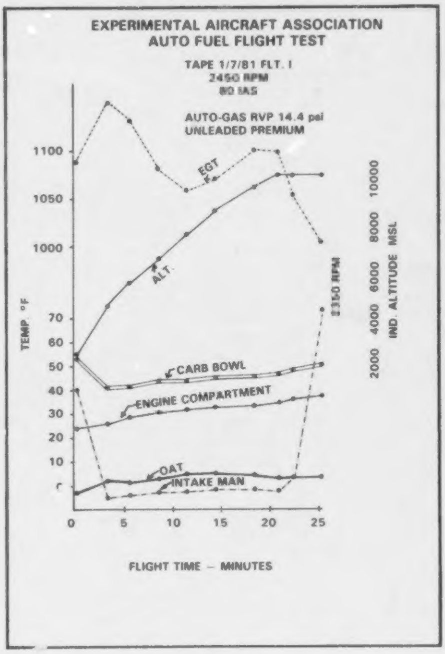


FIG. 8A

immediately after restart, the flow of fuel through the carburetor bowl quickly dropped to fuel tank temperature. Typical climb test data is shown on Figures 8, 8a, 8b.

C. Icing.
Icing conditions were sought but icing was not encountered even though the aircraft was flown through visible moisture at conditions expected to cause carburetor ice Test work going on at the same time with the same model engine at the FAA Technical Center in Atlantic City indicated that the carburetor icing would not be any more of a problem when using automobile gasoline, than it is when burning aviation gasoline. The carburetor heat control used in the conventional manner, dissipated the ice whether the engine was burning avgas or autogas.

D. Cooling Tests.
Cooling tests were conducted by stabilizing cylinder head temperatures and oil temperatures while flying at full power at the lowest practical altitude. After stabilization, the aircraft is then put into a normal climb at the minimum climb speed and held in that condition until the temperatures again peak at a new value for both cylinder heads and oil. Correction factors are applied to reduce all data to 100°F days as defined in the FAA Flight Test Report referenced above. Corrected temperatures did not exceed the limits established by the engine manufacturer of 240° F oil temperature and 525° F cylinder head temperature.

E. Hot Fuel.
Hot fuel tests per FAR 33.961 were conducted in accordance with FAR 33.961. For the official flight, continuous recording of the fuel tank temperature showed that the initial temperature was 114°F. The aircraft took off and entered a climb which was maintained until reaching service ceiling at 14,000 feet.

The lapse rate in the fuel temperature was approximately equivalent to the ambient temperature lapse rate. No indication of vapor lock occured under any conditions.

Tests were also conducted at 85°F ambient temperature with refrigerated 16 RVP fuel with no indication of vapor lock.

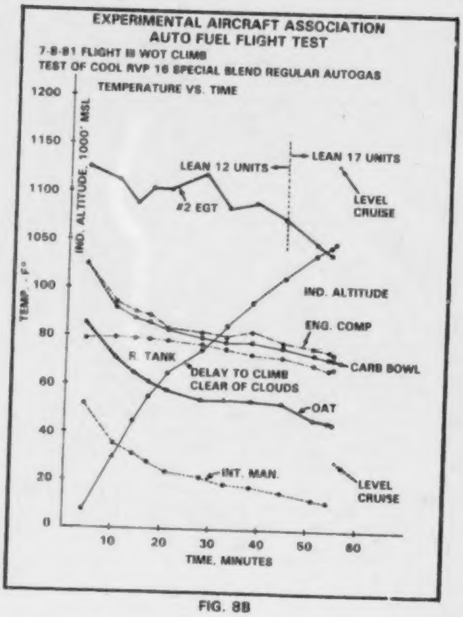


FIG. 8B

F. Climb Performance.
The general aircraft performance comparison was done by flight tests using first aviation gasoline and then switching to the main tanks and using autogas during the same flight operations. Book values for various conditions for flight

such as climb performance and cruising were taken from the aircraft operators manual and established for these comparisons. In all cases, performance on either fuel was identical. If there were any tendencies exhibited they show a slight improvement with automobile gasoline. In theory at least, this would seem to indicate the influence of a slightly higher BTU content of the fuel. See figures 9, and 9a, and 9b.

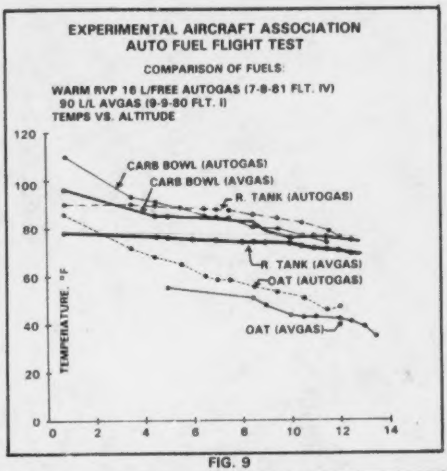


FIG. 9

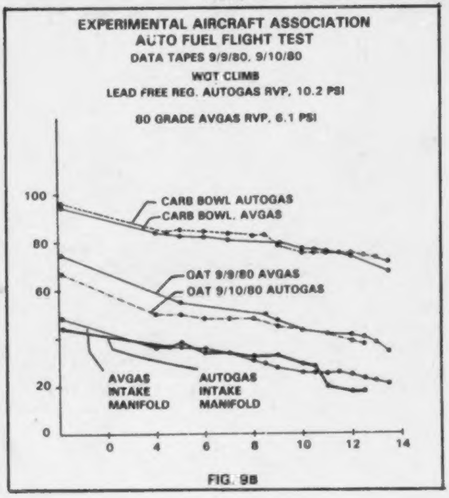


FIG. 9B

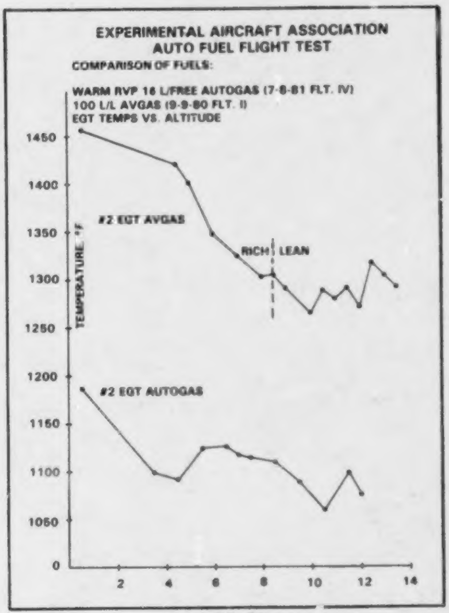


FIG. 9A

G. Detonation Tests.

The aircraft was instrumented with a Lebow Torque Meter, a Fisher Porter Flow Rater, and acceleration sensors mounted on the spark plug bodies. The aircraft was tied down for ground testing since in naturally aspirated engines, this is critical altitude. See figures 10, 11 and 11a.

Test runs were then made recording data on the Fluke equipment as installed for flight testing and manually recording data from the torque meter and flow meter. Carburetor air intake was kept above 100 F and the carburetor throttle maintained in a wide open position. Fuel flow was reduced by the mixture control until cylinder head temperatures exceeded the maximum limits by 50 F. Data from the acceleration sensors was noted on an oscilliscope and notations were made regarding insipient detonation. No actual detonation was encountered. The results are shown on figure 13.

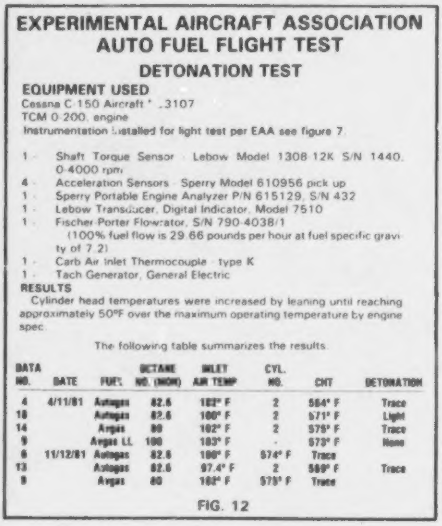
FIG. 10
ENGINE ANALYZER AND
TORQUE METER INSTALLED IN CABIN
FOR DETONATION TESTING

FIG. 11
VIBRATION PICK UPS AND
TORQUE METER INSTALLED
FOR DETONATION TESTING

FIG. 11A
FLOW METER AND
TORQUE METER INSTALLED
FOR DETONATION TESTING

H. Engine Condition.

Engine condition and wear characteristics were found to be comparable to that expected as normal with the use of 80 grade aviation gasoline. At the beginning of the test, this particular engine had 283 hours since a major overhaul, at which point, it was dismantled and critical parts measured as shown on figure 1. After running 610 hours, the engine was again torn down to the equivalent of a top overhaul and the critical parts measurement was officially witnessed by the FAA. The final teardown inspection took place after 610 hours of flight operation on automobile gasoline on April 15, 1981, and was again witnessed by the FAA. A representative oil analysis data sheet is shown on figure 13. A representative report on the analysis of a fuel sample is shown on figure 14. Figure 15 shows a comparison of major specification figures for avgas and autogas and average values of fuel used. See the photos in figures 16 through 29.



EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST
DETONATION TEST

EQUIPMENT USED

Cessna C-150 Aircraft " .3107
TCM 0-200, engine
Instrumentation installed for light test per EAA see figure 7.

1 - Shaft Torque Sensor - Lebow Model 1308-12K S/N 1440, 0-4000 rpm
4 - Acceleration Sensors - Sperry Model 610956 pick up
1 - Sperry Portable Engine Analyzer P/N 615129, S/N 432
1 - Lebow Transducer, Digital Indicator, Model 7510
1 - Fischer-Porter Flowrator, S/N 790-4038/1 (100% fuel flow is 29.66 pounds per hour at fuel specific gravity of 7.2)
1 - Carb Air Inlet Thermocouple - type K
1 - Tach Generator, General Electric

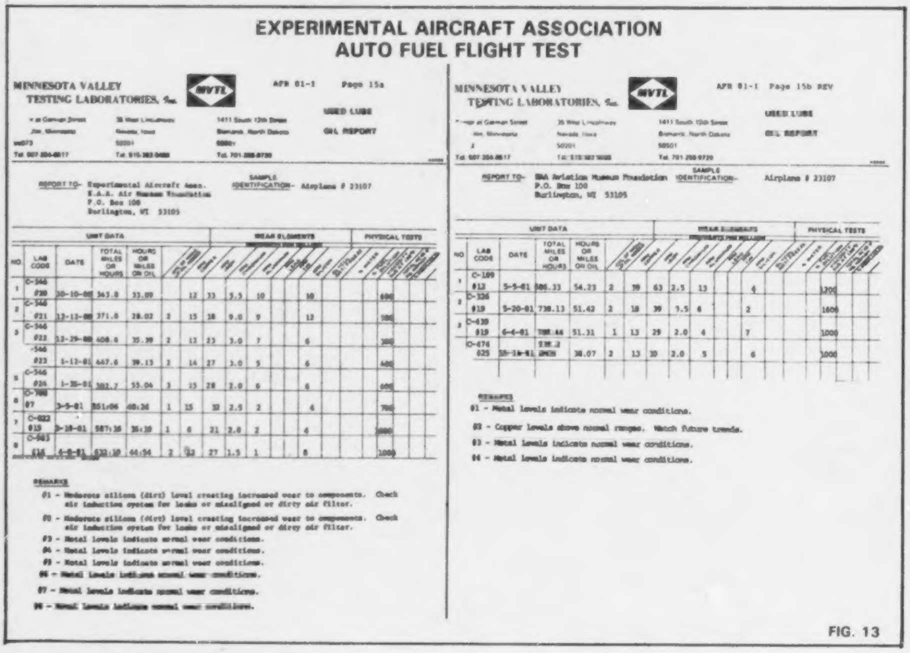
RESULTS

Cylinder head temperatures were increased by leaning until reaching approximately 50°F over the maximum operating temperature by engine spec.

The following table summarizes the results.

DATA NO.	DATE	FUEL	OCTANE NO. (MON)	INLET AIR TEMP	CYL. NO.	CHT	DETONATION
4	4/11/81	Autogas	82.6	102° F	2	564° F	Trace
10		Autogas	82.6	100° F	2	571° F	Light
14		Avgas	80	102° F	2	575° F	Trace
9		Avgas LL	100	103° F	-	573° F	None
6	11/12/81	Autogas	82.6	100° F	574° F	Trace	
13		Autogas	82.6	97.4° F	2	569° F	Trace
9		Avgas	80	102° F	575° F	Trace	

FIG. 12



EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

MINNESOTA VALLEY
TESTING LABORATORIES, Inc.

APR 81-1 Page 15a

USED LUBE
OIL REPORT

REPORT TO- Experimental Aircraft Assn.
E.A.A. Air Museum Foundation
P.O. Box 100
Burlington, WI 53105

SAMPLE IDENTIFICATION- Airplane # 23107

UNIT DATA					WEAR ELEMENTS									PHYSICAL TESTS				
NO	LAB CODE	DATE	TOTAL MILES OR HOURS	HOURS OR MILES ON OIL														
1	C-346 #20	10-10-80	343.0	33.09		12	33	5.5	10			10				600		
2	C-346 #21	12-12-80	371.0	28.02	2	15	38	9.0	9			12				300		
3	C-346 #22	12-29-80	408.6	35.39	2	12	23	3.0	7			6				300		
	-346 #23	1-12-81	447.6	39.13	2	14	27	3.0	5			6				400		
5	C-346 #24	1-30-81	502.7	55.04	3	15	28	2.0	6			6				600		
6	C-700 #7	3-5-81	501:06	40:36	1	15	32	2.5	2			4				700		
7	C-022 #13	3-18-81	587:36	35:10	1	6	21	2.0	2			4				1000		
8	C-503 #16	4-8-81	632:10	44:54	2	12	27	1.5	1			8				1000		

REMARKS

#1 - Moderate silicon (dirt) level creating increased wear to components. Check air induction system for leaks or misaligned or dirty air filter.
#2 - Moderate silicon (dirt) level creating increased wear to components. Check air induction system for leaks or misaligned or dirty air filter.
#3 - Metal levels indicate normal wear conditions.
#4 - Metal levels indicate normal wear conditions.
#5 - Metal levels indicate normal wear conditions.
#6 - Metal levels indicate normal wear conditions.
#7 - Metal levels indicate normal wear conditions.
#8 - Metal levels indicate normal wear conditions.

MINNESOTA VALLEY
TESTING LABORATORIES, Inc.

APR 81-1 Page 15b REV

USED LUBE
OIL REPORT

REPORT TO- EAA Aviation Museum Foundation
P.O. Box 100
Burlington, WI 53105

SAMPLE IDENTIFICATION- Airplane # 23107

UNIT DATA					WEAR ELEMENTS									PHYSICAL TESTS				
NO	LAB CODE	DATE	TOTAL MILES OR HOURS	HOURS OR MILES ON OIL														
1	C-189 #12	5-5-81	686.33	54.23	2	39	63	2.5	13			4				1200		
2	C-326 #19	5-20-81	730.13	51.42	2	18	39	5.5	6			2				1600		
3	C-439 #19	6-4-81	[illegible]	51.31	1	13	29	2.0	4			7				1000		
	C-474 #25	10-16-81	[illegible]	38.07	2	13	30	2.0	5			6				1000		

REMARKS

#1 - Metal levels indicate normal wear conditions.
#2 - Copper levels above normal ranges. Watch future trends.
#3 - Metal levels indicate normal wear conditions.
#4 - Metal levels indicate normal wear conditions.

FIG. 13

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

TYPICAL FUEL INSPECTION DATA

Sample	A Unleaded Purchased From Hills Handy Pantry Burlington, WI 9/24/81	B Unleaded Burlington, WI Rated 87 Oct Min. 9/27/81	C Unleaded Purchased From Burlington S/S 9/28/81	D Unleaded Purchased From Fred's S/S [illegible] 9/30/81	E Westbend 100 L/L AV 10/7/81	F Hartford 100 L/L AV 10/7/81	G Hodge Aero Janesville 100 L/L AV No Date
Distillation, °F							
Initial	86	86	87	86	101	100	100
5	94	97	102	104	142	141	140
10	111	111	114	116	155	157	155
30	170	162	160	168	190	199	197
50	218	218	224	219	209	216	214
70	265	272	280	266	218	224	224
90	346	342	341	336	229	241	245
95	380	374	370	362	239	260	264
End Point	424	417	417	400	283	310	312
Reid Vapor Pressure, psi	10.5	10.6	10.3	10.2	5.4	5.5	5.7
Gravity, °API	60.7	59.6	58.0	60.1	66.4	69.9	69.6
V/L, ^{T}20	128.0	127.0	128.0	130.0	161.0	161.0	161.0
Hydrocarbon Type							
Paraffins-Naphthenes	70.0	63.2	62.3	66.0	81.5	92.5	91.0
Olefins	3.2	5.5	2.4	3.0	1.8	0.7	0.7
Aromatics	26.8	31.3	35.3	30.1	16.7	6.8	7.4
Gums, mg/100 ml							
Prewash	2.4	3.5	2.8	16.7	1.4	1.3	0.8
Washed	2.2	2.6	1.7	1.6	0.0	0.1	0.0
Particulate Contaminants mg/gal	0.6	0.8	0.9	0.9	4.2	2.1	2.8
RON	91.7	91.9	91.6	91.7	NOT RATED		
MON	83.5	83.0	83.0	83.6			
R + M/2	87.6	87.5	87.3	87.7			

Sample	H Downtown Iowa City 11/8/81	I Reg. L/F MKC/Olathe Johnson County 11/9/81	J 80 Oct. AV Gas 1 CT Bot. Test High Point Estates 11/10/81	K 100 Oct. L/L AV Gas High Point Estates 11/11/81	L Reg. L/F Auto Fuel Valley Center, KS 11/12/81
Distillation, °F					
Initial	91	90	11	100	84
5	116	105	142	136	106
10	130	119	153	151	118
30	184	173	179	192	166
50	230	222	201	213	222
70	274	267	217	224	260
90	338	333	239	246	330
95	360	359	262	275	360
End Point	410	405	325	334	416
Reid Vapor Pressure, psi	8.3	9.8	5.2	5.6	9.8
Gravity, °API	53.8	56.0	72.8	72.5	60.8
V/L, ^{T}20	145.0	133.0	160.0	158.0	129.0
Hydrocarbon Type					
Paraffins-Naphthenes	56.4	58.8	97.1	95.0	68.7
Olefins	4.7	4.7	1.1	1.4	3.8
Aromatics	38.9	36.5	1.8	3.6	27.5
Gums, mg/100 ml					
Prewash	7.2	7.3	1.8	1.4	2.3
Washed	2.6	3.4	0.0	0.0	0.6
Particulate Contaminants mg/gal	0.8	22.3	0.0	0.9	0.6
RON	93.6	93.0	NOT RATED		91.4
MON	82.9	82.6	NOT RATED		83.4
R + M/2	88.3	87.8	NOT RATED		87.4

	M Unleaded J&L Oil Co. 3/5/82	N Unleaded Auto Fuel Elkhorn, WI 4/10/82
Distillation, D-86 % Evaporated, °F		
IBP	84	86
5	96	102
10	105	115
30	150	169
50	200	222
70	266	269
90	346	344
95	378	377
EP	418	427
Loss, %	2.0	2.5
Rvp, psi	13.1	10.8
Gravity, °API	62.1	59.7
$T_{V/L}$ = 20	112.0	128.0
HCTA, v.%		
PN	64.0	62.0
O	8.5	7.0
A	27.5	31.0
D-381 Gum, mg/100 cc		
Prewashed	3.7	3.4
Washed	0.8	2.0
Particulate Contaminants mg/gal	1.7	1.7
RON	91.5	90.9
MON	82.9	82.5
R + M/2	87.2	86.7

FIG. 14

EXPERIMENTAL AIRCRAFT ASSOCIATION AUTO FUEL FLIGHT TEST

FUELS COMPARISON

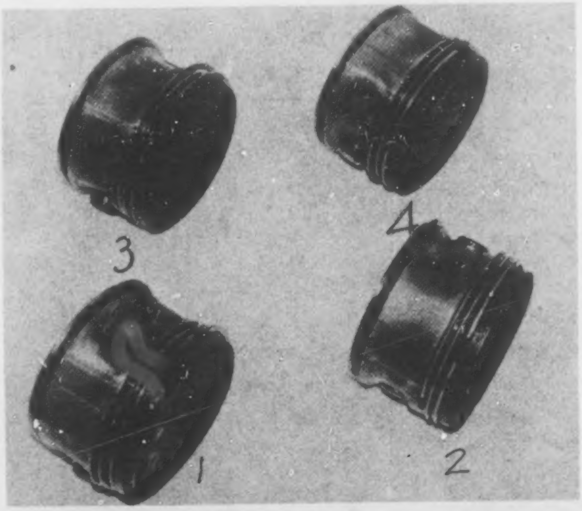
	80 Grade Avgas Specification ASTM D-910	Lead Free Regular Grade Autogas Specification ASTM D-439	Actual Autogas Used Average Values
Distillation Characteristics			
10%	167°F	122°F	113.4°F
50%	221°F	170-230°F	214.5°F
90%	338°F	437°F	406.7°F
RVP psi max	7	15	11.4
Gum mg/100ml.	6	5	1
Aromatics	no requirement Heat value limits to approx. 25%	no requirement 25 to 40% current values	36.2%
Octane No. (Motor Method)	80	$\frac{R+M}{2}$=87 min. Minimum MON=82	83

Distillation 10% value - relates to cold starting and warm-up
50% value - relates to carburetor icing
90% value - relates to performance and economy

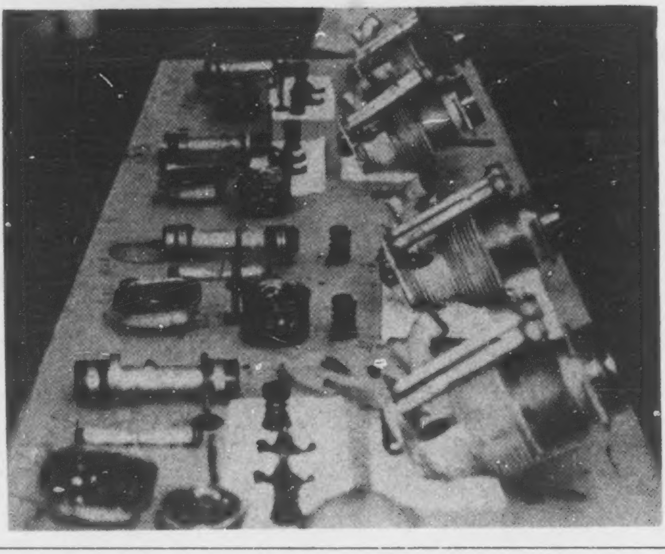
FIG. 15

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

FIG. 16



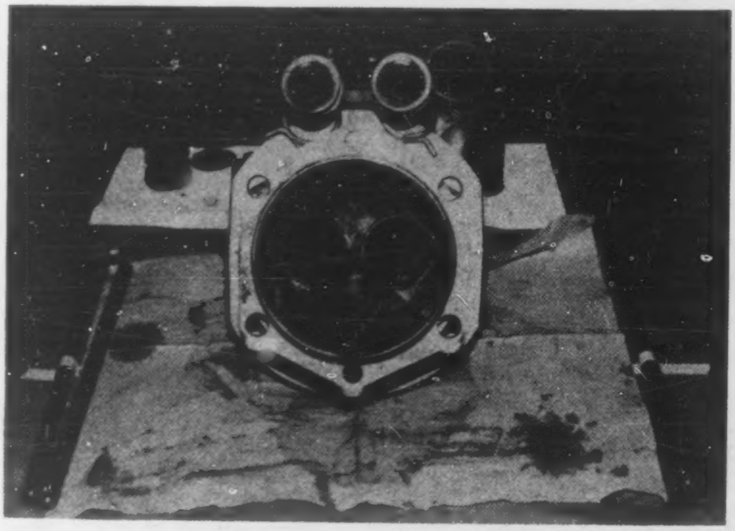
PISTONS 283 HRS.
- AFTER MAJOR OVERHAUL
- AV-GAS
- BEFORE START OF AUTO FUEL TEST



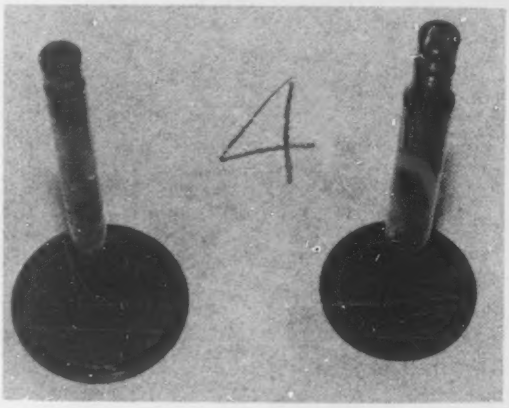
TCM 0-200 ENGINE INSPECTION,
283 HRS.
- AFTER MAJOR OVERHAUL
BEFORE START OF AUTO FUEL TEST

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

FIG. 17



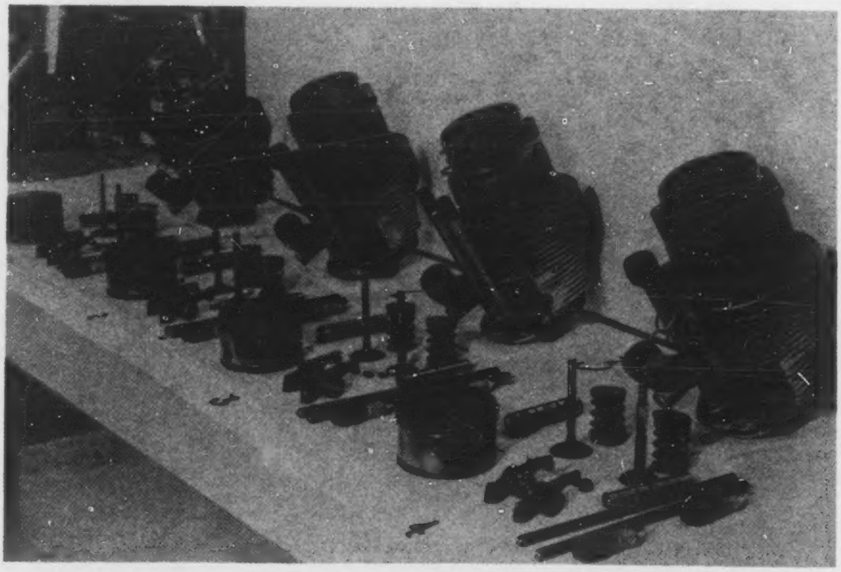
NO. 4 CYLINDER - 283 HRS. AV-GAS - BEFORE START OF AUTO FUEL TEST



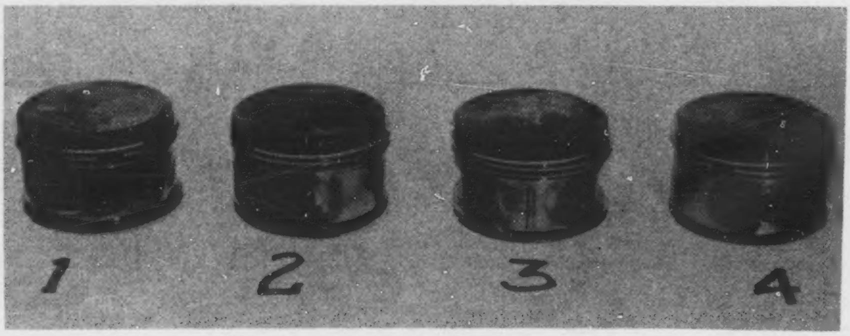
NO. 4 VALVES - LEFT: INTAKE - RIGHT: EXHAUST - 283 HRS. AV-GAS BEFORE START OF AUTO FUEL TEST

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

FIG. 18



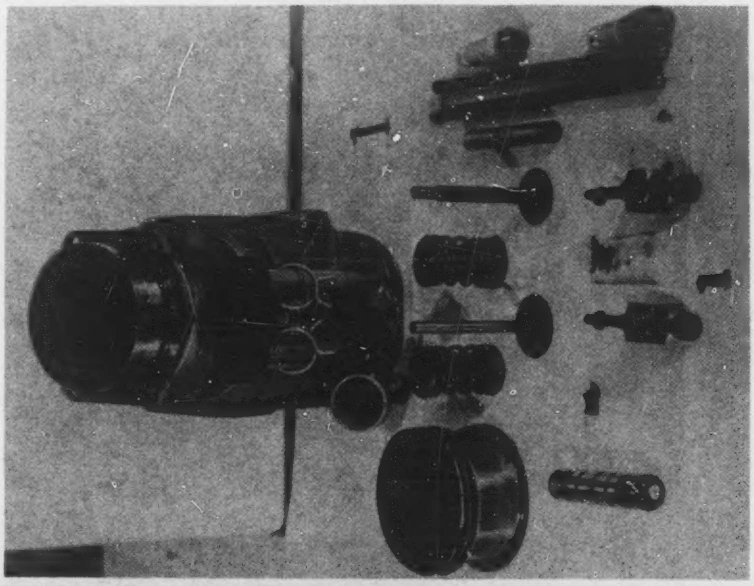
FINAL ENGINE INSPECTION - 893 HRS. SINCE OVERHAUL - 610 HRS. USING AUTO-GAS



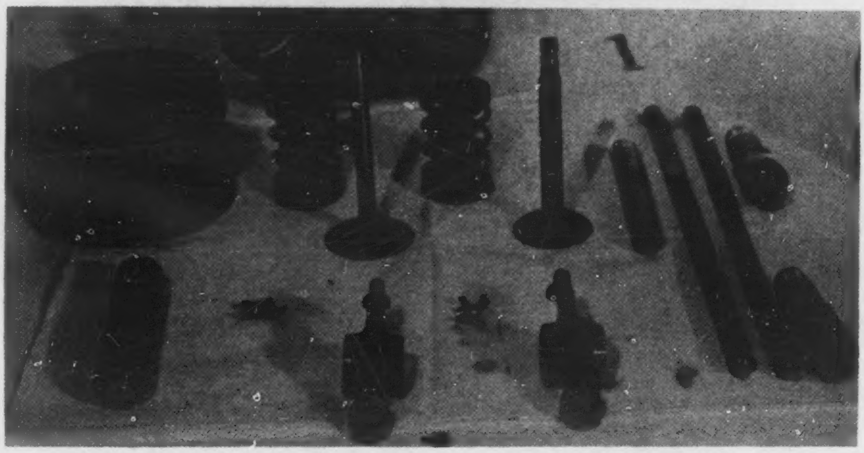
PISTONS - 610 HRS. AUTO-GAS

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

FIG. 19



NO. 1 CYLINDER - DISASSEMBLED PRIOR TO CLEAN-UP AND MEASURING - 610 HRS. AUTO-GAS



NO. 1 CYLINDER - DISASSEMBLED PRIOR TO CLEAN-UP AND MEASURING - 610 HRS. AUTO-GAS

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST
610 HRS. AUTOGAS

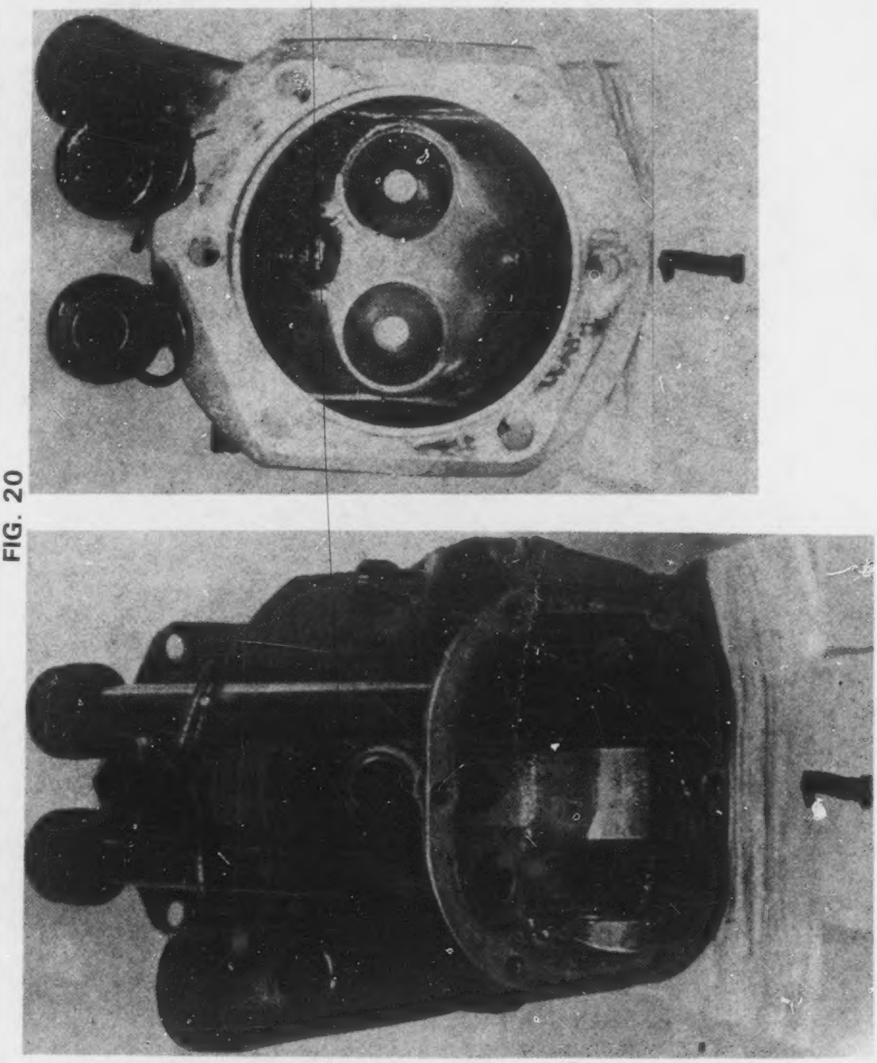
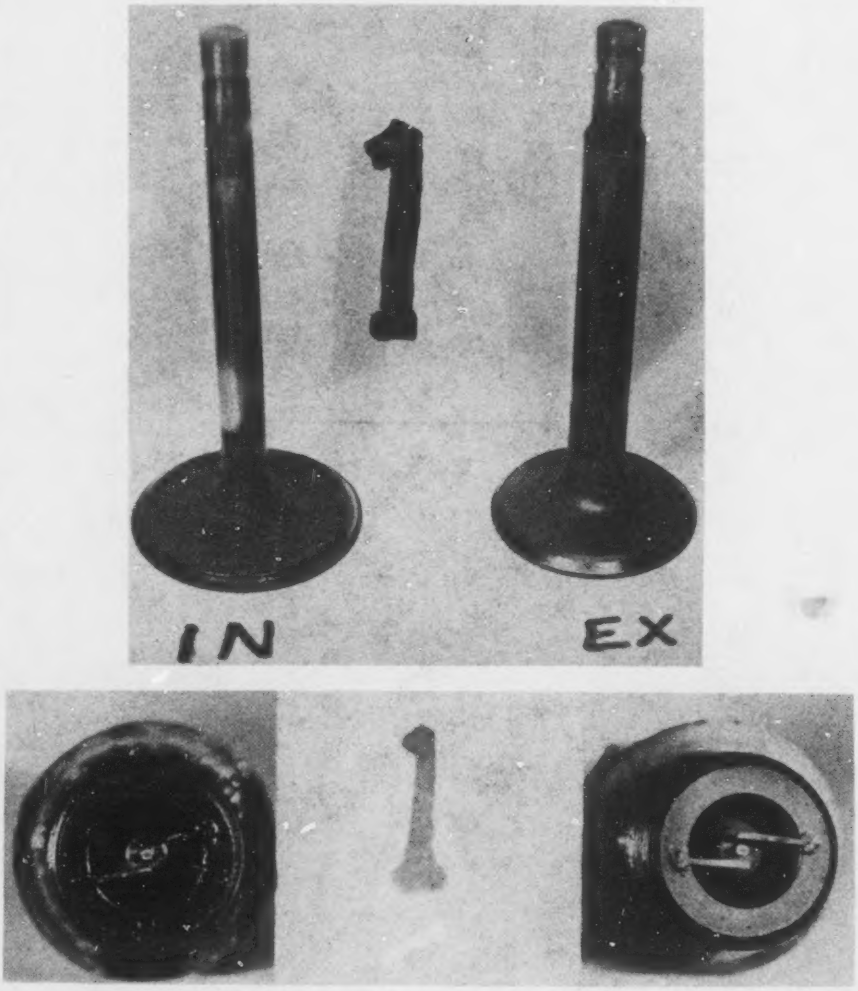


FIG. 20

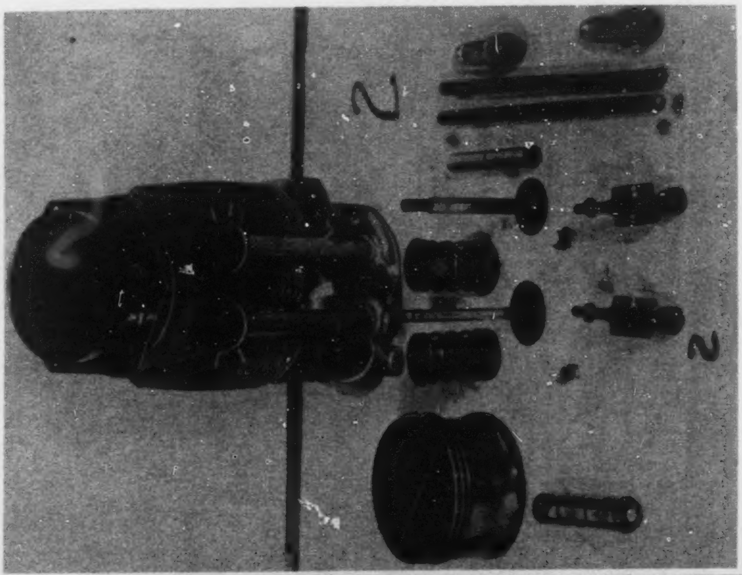
EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

FIG. 21

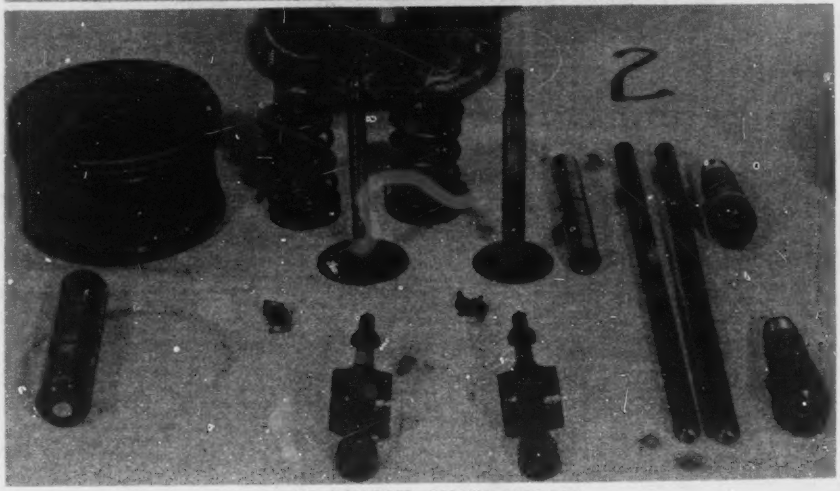


VALVES AND SPARK PLUGS - 610 HRS. AUTO-GAS

FIG. 22



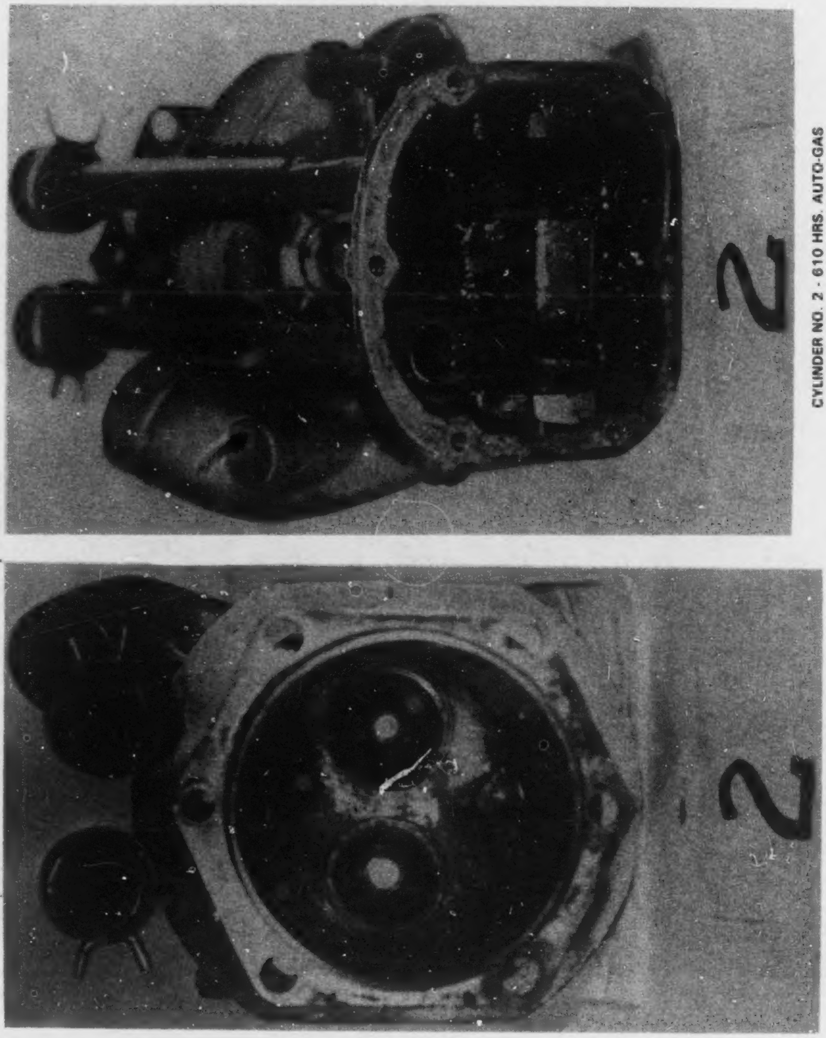
NO. 2 CYLINDER - 610 HRS. AUTO-GAS



NO. 2 CYLINDER - 610 HRS. AUTO-GAS

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

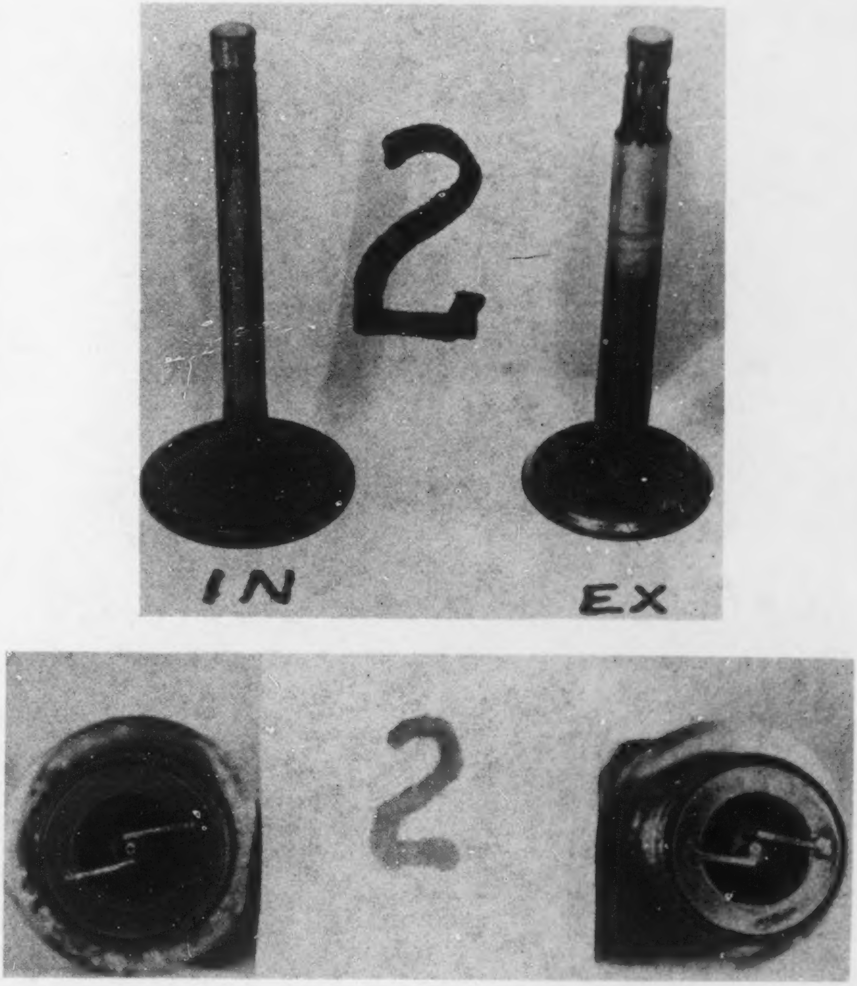
FIG. 23



CYLINDER NO. 2 - 610 HRS. AUTO-GAS

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

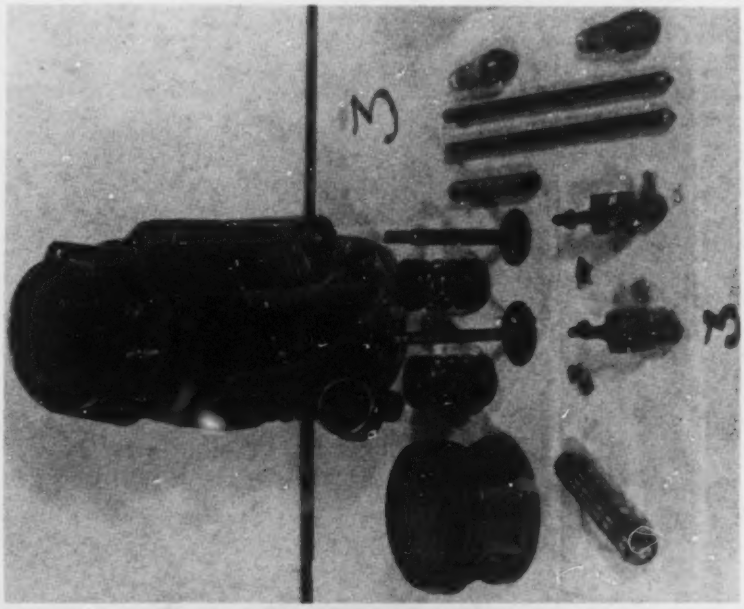
FIG. 24



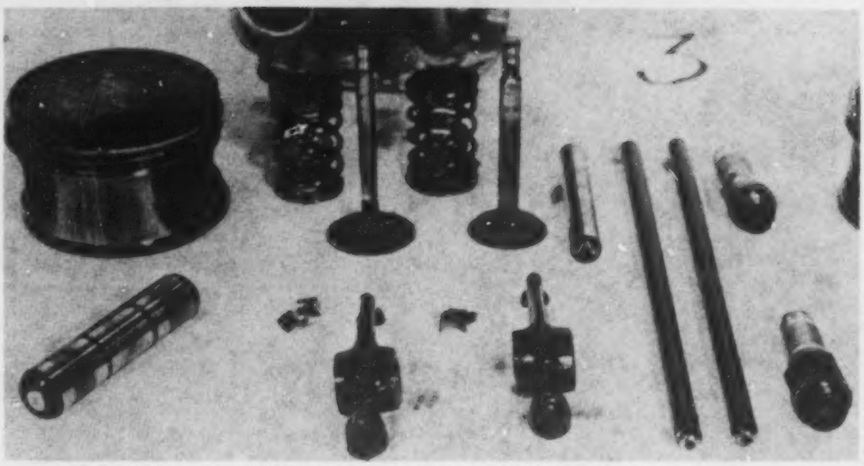
FROM NO. 2 CYLINDER - 610 HRS. AUTO-GAS

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

FIG. 25



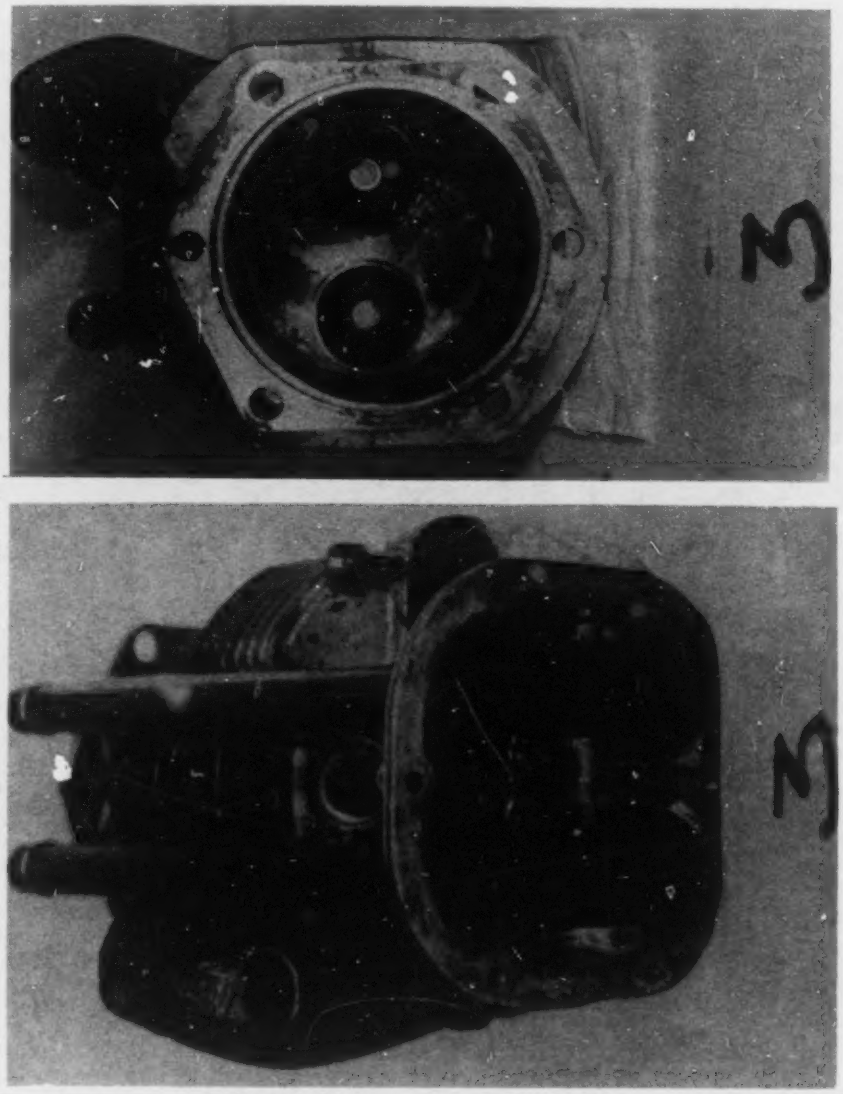
NO. 3 CYLINDER - DISASSEMBLED PRIOR TO CLEAN-UP AND MEASURING - 610 HRS. AUTO-GAS



NO. 3 CYLINDER - DISASSEMBLED PRIOR TO CLEAN-UP AND MEASURING - 610 HRS. AUTO-GAS

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

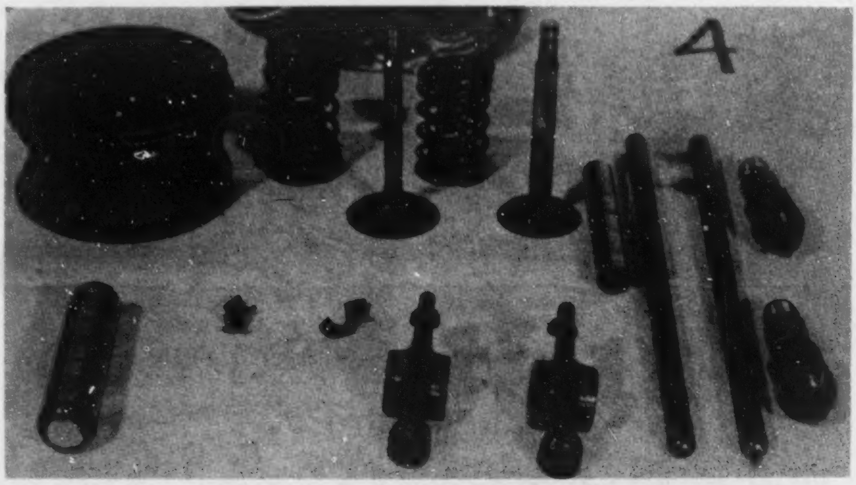
FIG. 26



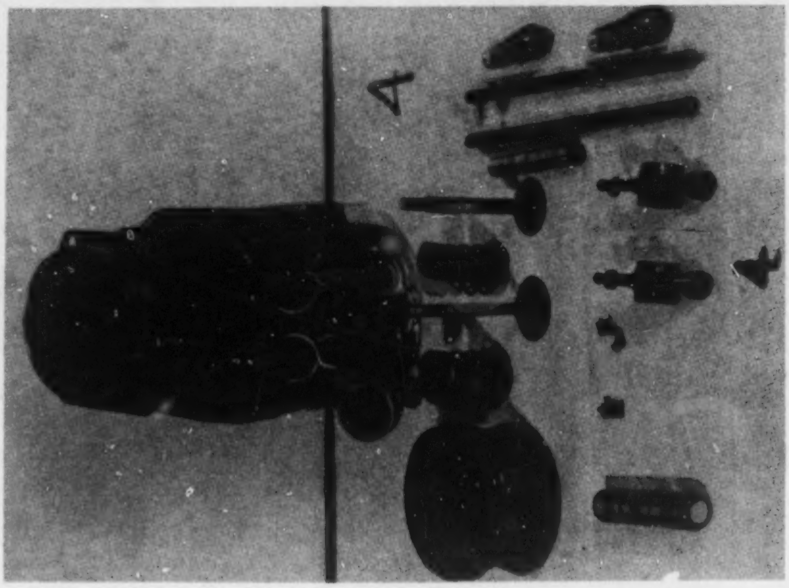
NO. 3 CYLINDER - 610 HRS. AUTO-GAS

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

FIG. 27



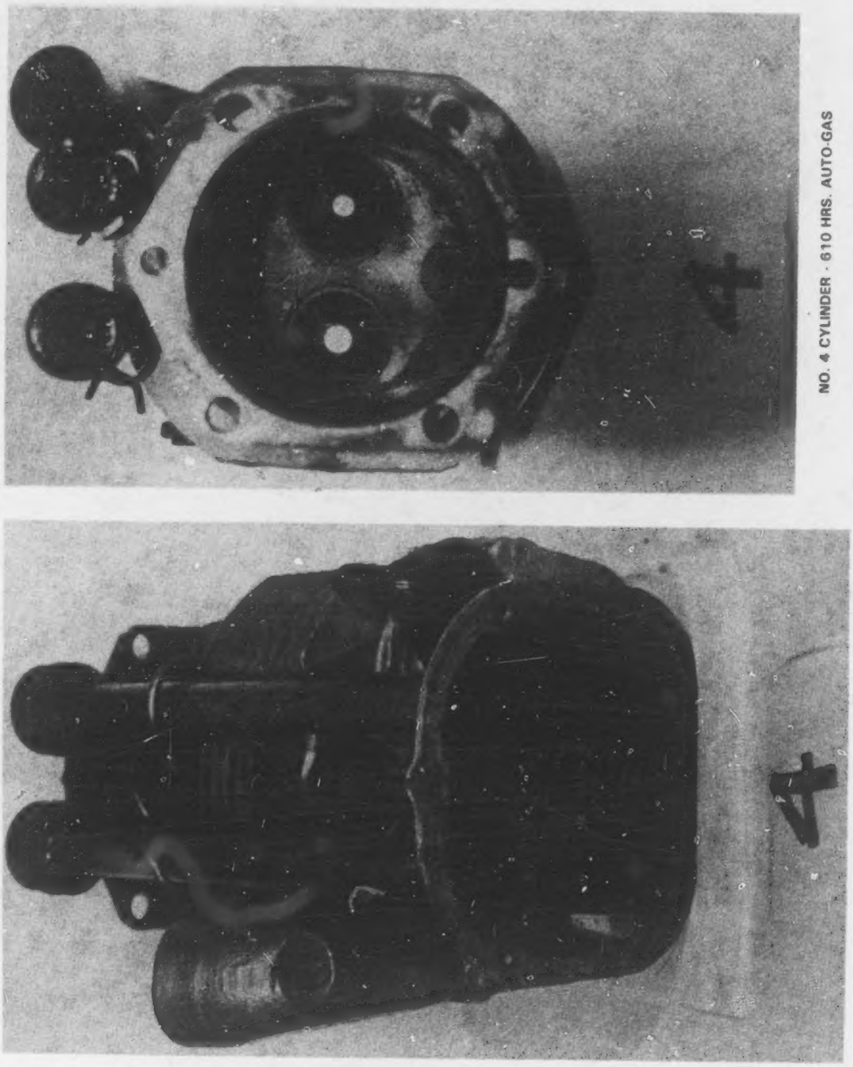
CYLINDER NO. 4 - 610 HRS. ON AUTO-GAS



CYLINDER NO. 4 - 610 HRS. ON AUTO-GAS

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

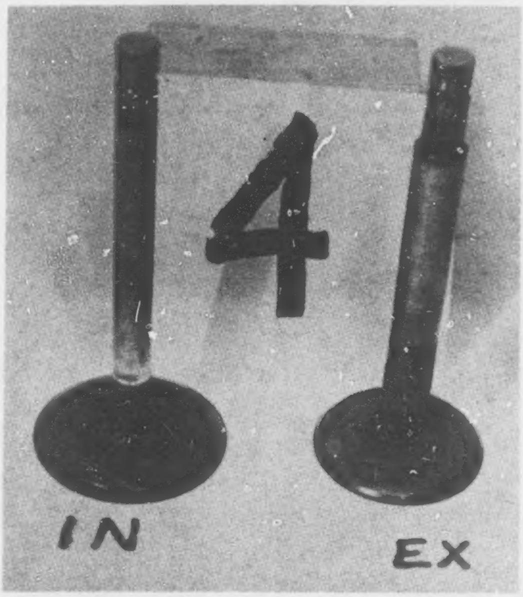
FIG. 28



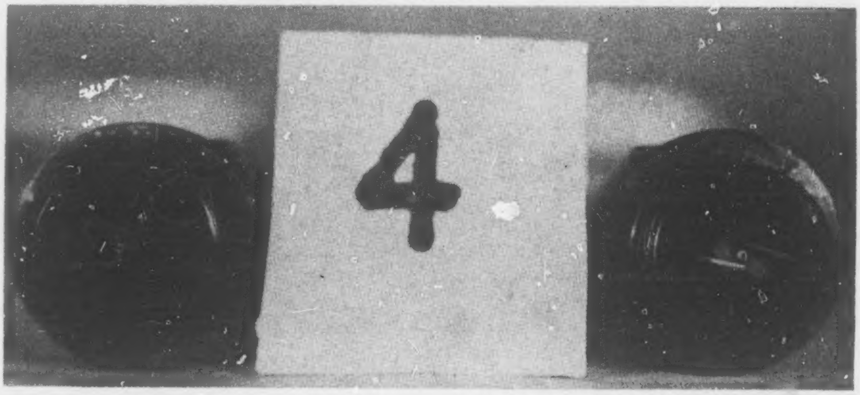
NO. 4 CYLINDER - 610 HRS. AUTO-GAS

EXPERIMENTAL AIRCRAFT ASSOCIATION
AUTO FUEL FLIGHT TEST

FIG. 29



VALVES - 610 HRS. AUTO-GAS



SPARK PLUGS - 610 HRS. AUTO-GAS

I. FAA Approval.

Supplemental Type Certificates #SA 633 GL and SE 634 GL were granted to the EAA for the airplane and for the engine.

1. Requirements.

These STC's require that an approved flight manual supplement be carried in the aircraft. This document defines the approved fuel as regular unleaded automobile gasoline having an antiknock index number of 87 and complying with ASTM specification D-439. Using any mixture of automobile gas and aviation gasoline must be considered to be operating on automobile fuel.

Placards must be installed by each fuel tank filler neck noting the approval of autogas.

Idle rpm must be set to 700 rpm minimum. The Teledyne Continental motors overhaul and service manual notes that when this engine is operated on aviation gasoline and throttle is violently and/or improperly handled during a landing roll, it is possible that the engine may stop. This occurred also when using automobile gasoline. However, during these tests when the idle speed was increased from 650 rpm to 700 rpm it was no longer possible to make the engine stop through extreme manipulation of the throttle. This 700 rpm requirement was then made a part of the STC as noted above.

2. Limitations.

There are no operational limits imposed because of the use of automobile gasoline. The FAA has advised that until additional experience is gained they will issue a field order withholding approval for FAR part 121 operations (scheduled air line service), and for part 135 operations, (air taxi service). All other operations are approved: Far part 91 (general operation) and part 141 (flight school operation). This airplane when conforming to the STC, can be operated commercially, for hire, and for flight training as well as for personal, business, and pleasure when using automobile gasoline.

RECOMMENDATIONS

1. Continue automobile gasoline testing on all 80 octane aircraft engines. Initiate testing on low wing aircraft and complex fuel systems.

2. Simplify the present gasoline specifications to cover only the essential features.

3. Request the FAA to undertake a program to simplify the evaluation and approval of automobile fuels for aircraft, in view of the recognized problems of availability and cost of aviation gasoline and the demonstrated satisfactory operation here and in the United Kingdom.

4. FAA should immediately revise erroneous and misleading FAA publications regarding the use of automobile gasoline.

5. Aircraft manufacturers have the technical knowledge and capability necessary to design personal type aircraft with fuel systems capable of safely handling automobile gasoline throughout all conditions of flight. This would be a most welcome step towards a reduction in the cost of personal flying, and should be done for all new production piston engine aircraft.

REFERENCES:

1. "The Impact of Petroleum, Synthetic, and Cryogenic Fuels on Civil Aviation," by Charles L. Blake. Report number DOT/FAA/EM-82/29. Available through NTIS.
2. "FAA ADVISORY CIRCULAR NUMBER AC91-33". Use of alternate grades of aviation gasoline for grade 80/87.
3. DOE/BETC/PPS-76/1 thru 81/3 Motor Gasolines, by Ella Mae Shelton Bartlesville Energy Technology Center, P.O. Box 1398, Bartlesville, Oklahoma 74003.
4. SAE Report 541 "Recommendations For Fuel System Design For Personal Aircraft with Regard to Vapor Lock", by LL. York, Continental Motors - A. Hundere, California Research Corp. - and R.A. Coit, Shell Development Company, November 1950.
5. Al Hundere, Alcor, in AOPA Pilot Magazine October 1969, Pg. 48.
6. FAA Service Difficulty Program tab run on Cessna 150, with TCM 0-200A engine, Marvel-Schebler carburetor. Code 7322. Available from AOPA, P.O. Box 19244, Oklahoma City, Oklahoma.
7. FAA Advisory Circular Number AC20-24 Method of approval of alternate fuels and lubricants.

Mr. Glickman. Thank you very much, both of you, for your testimony.

I would just like to ask you a few basic questions. Harry, the staff tells me they have had some discussions with GAMA, the General Aviation Manufacturers Association, on the exact subject which you just talked about. And based upon our understanding of their position, they are going to be here—and they can correct me if I am wrong—is it acceptable for them to arbitrarily condone the use of either of the 100 octane av-gases without recertification test programs in the detail being required for auto gas?

Mr. Zeisloft. I am not sure I understood your question, Mr. Glickman. The GAMA, of course, doesn't have much to do any more with 80 octane engines, since the elimination, or the hoped for elimination of the 80 octane fuel. Most new engines have been converted to higher compression and use 100 octane fuel. So it is hard to say what their attitude would be there. However, I would expect that in view of the potential savings to the ultimate customer, they would want to give some consideration to this substitution.

Mr. Glickman. Well, we will hear more from them when they give their testimony on this point.

What is the current status of the use of automobile gasoline?

Mr. Zeisloft. Currently automobile gasoline is approved for use in Cessna 120, Cessna 140, 140A, 150, Cessna 180 and 182, which represents about, roughly about a third of the 80 octane fleet.

Mr. Glickman. And what is the FAA's position now on certification of automobile gasoline in airplanes?

Mr. Zeisloft. After our initial Indian wrestle with them, to get the withdrawal of the ban against automobile gasoline, they have been very cooperative and have been very helpful in helping us understand what the requirements were for certification, and I think between the two of us we have made great progress in the last year.

Mr. Glickman. Were they quite reluctant up until a year or two ago in making any changes in this area?

Mr. Zeisloft. Yes; I think you would have to say that.

Mr. Glickman. What is the future of that? How far can we go in automobile gasoline in aircraft?

Mr. Zeisloft. Well, our future plan is aimed at getting approvals for all 80 octane powered engines, and aircraft, and that means a high wing, low wing, complex fuel system, and so on. Now, there may have to be some changes in some of the more complicated fuel systems. I don't see these applications as complications for the private owner.

After that, we feel it is worthwhile to investigate the potential for utilizing automobile gasoline as a basic stock for 100 octane engines, and I think the future, with some of this technical information that we would hope that can be obtained from NASA, we would expect that the entire fleet could be using automobile gasoline.

Mr. Glickman. The entire fleet of aircraft?

Mr. Zeisloft. Yes.

Mr. Glickman. And again, which aircraft, the entire fleet of——

Mr. Zeisloft. Piston engine aircraft.

Mr. Glickman. Piston engine aircraft?

Mr. ZEISLOFT. Yes.

Mr. GLICKMAN. If auto gas is used basically, will it reduce demand to the extent that its disuse will cause aviation gas to disappear from the market?

Mr. ZEISLOFT. I would expect so.

Mr. GLICKMAN. What is the consequence of that?

Mr. ZEISLOFT. Improved economics in the aviation field, I would expect.

Mr. GLICKMAN. But is there any down side?

Mr. ZEISLOFT. I would say that when people can afford to fly they are going to fly more and use more services, use more parts and buy more airplanes, and that is the ultimate incentive for us to spend our time and effort in this field.

Mr. GLICKMAN. Is there any down side to current users of 100 octane aviation gas? I mean is there any down side to this kind of thing?

Mr. ZEISLOFT. Yes; the octane situation is not a simple one. It is highly technical and complex, and there is no way in the world that I can see right now to say that automobile gasoline will have a high enough octane grade to be a simple substitute in 100 octane engines such as it is in an 80 octane engine. So there will have to be some compromises and some adjustments made, possibly in the fuel, possibly in the aircraft, more likely in both.

Now, this could be done today, immediately, in my estimation, by simply limiting the power output. How we see that in this trainer that Beech is flying, they have taken a 9 percent power loss because of the economies of the fuel. It is that sort of a situation that could exist right now in flying 100 octane engines on presently available premium auto gas, which would mean that you would limit the operating envelope.

Mr. GLICKMAN. That has got a safety problem to it, though?

Mr. ZEISLOFT. That is the purpose for limiting the envelope, to insure that the power output is at a level which will not cause detonation with that octane fuel, and this is common practice in aircraft. You redline instruments and say never go over that, and you give instructions in your operating manual and say don't operate in this area. And that is an immediately available situation which would represent a decrease in performance, of course.

Mr. GLICKMAN. I would ask that—so, therefore, then, in conclusion, you think that the technology is there to convert the entire piston fleet to auto gas?

Mr. ZEISLOFT. Yes, I do.

Mr. GLICKMAN. And do it without jeopardizing any safety consideration, and the plus side is the economics of the picture which you said could be as much as $300 million a year?

Mr. ZEISLOFT. Yes.

Mr. GLICKMAN. I do think that in light of the previous oil cutoffs and the allocation problems where we could not get av-gas, that your efforts are quite productive, because in the event that we have another problem, I don't think that av-gas is going to be a high priority, as it wasn't before, anymore than what we do in Washington to try to get the regulators to change that, so I think your efforts are useful.

Let me ask Mr. Adkins, what kind of certification do you have for the Sundowner? Is it supplemental type certification?

Mr. MAGRI. No, sir, it is not. It is flying on an experimental ticket.

Mr. GLICKMAN. Are there any aircraft flying today, or on any of the fuels that you mentioned, that have anything other than an experimental type certification?

Mr. ADKINS. The French are going for supplemental type certification on an aircraft that is similar to the Sundowner.

Mr. GLICKMAN. Using what kind of fuel?

Mr. ADKINS. Using propane on that one. And there is another operation, agricultural operation in southeast Missouri that is using propane also in rotary wing aircraft in crop dusting, and they are going for supplemental type certification. And all that we would do to change from the propane fuel to the LNG fuel are those aircraft.

Mr. GLICKMAN. Has your work with the Sundowner as of yet indicated any peculiar problems to operating an aircraft on methane?

Mr. MAGRI. Light load.

Mr. ADKINS. Not much—just the performance degradation we mentioned.

Mr. GLICKMAN. But nothing in terms of maintenance?

Mr. MAGRI. No; its performance.

Mr. ADKINS. That is one of the things that the Army is looking at. They have a significant maintenance problem on the fouling of that aircraft, of the TH-55. It costs a considerable amount to send a crew out to the swamps there in Alabama and bring the helicopters and the crew back and one of the things that they look at is not only the normal reduction in maintenance costs, but the reduction in maintenance costs of having all those support people out retrieving the helicopters and the crews. We anticipate the same type of maintenance cost reductions.

Mr. GLICKMAN. OK. You talked about fleet use. What would be your best recommendation in terms of individual use for aircraft for alternative fuels? I mean, are we talking about the conversion to methane being an appropriate situation for somebody who owns a single, twin engine, or single engine aircraft? And if methane is not useful, is there anything that is useful?

Mr. ADKINS. I am afraid that the aviation field is in the same boat as you and I in the private sector are, that the infrastructure is just not there for the private individual—for the private aircraft owner. I think that is probably 5 or 7 years downstream now. Our immediate goals are to concentrate in the fleet area, develop the industry, and to get the operational experience behind us before going after the broad individual applications.

Mr. GLICKMAN. And my final question, before I turn it over to Mr. Carney, concerns the level of Government assistance. You and I worked very hard to get some legislation passed which would set up a separate methane program in the Department of Energy. I wonder if you could give me your assessment of the Department of Energy's work in this area?

Mr. ADKINS. Well, the Department has moved ahead with three studies. The analysis of the institutional barriers, which are probably foremost, and the results of that study, are quite encouraging, at least to us in the industry. The area of engine technology is another one that they have moved ahead in. The relative hazards study program that was instituted has several shortcomings. There were no actual tests done. Those type of tests still need to be done today.

Other than that, I would say that the assessment studies that have been accomplished by the DOE are fairly on target, and that the three studies that I mentioned are going to be well worthwhile. But more importantly, I feel that some of the things that are lacking right today is a national standard for the design and the certification of methane fuel systems, and I mean in both the compressed and the liquid states.

The second thing that is lacking is a consistent policy from the Environmental Protection Agency, whereas in 1971 and 1972, the agency was at the forefront or acting as the point for this program. Their attitude and their actions regarding the use of CNG and liquified systems, in conjunction with emission control equipment, have been inconsistent.

Also, their action and their responses to the nonreactive hydrocarbon aspects of using liquified methane or compressed methane. As you know, for stationary engines, they do not recognize the nonreactive hydrocarbon type emission, whereas in mobile applications in an automobile, they do count as a reactive hydrocarbon, when in reality it is not a reactive hydrocarbon and does not cause smog and that needs to be resolved, and would help tremendously in influencing certain fleet operations to move ahead.

What we have to do today is operate on an individual case-by-case basis and do the work from the civic organizations right up through the municipal government and the municipal service organizations, where if we could point to some effort at the national level and from the EPA, what is being done, it would be most helpful.

And then the third area, the Department of Energy has sponsored a number of programs through the Department of Agriculture to universities—over 100 of them—on methane production, from biomass, from sewage, from animal wastes. They have told them now to produce it, but they haven't told them what to do with it after they produce it. We feel that should be added.

We receive calls daily, I would say, from agricultural operations that want to know what to do with this biomass, and in that regard we are working with several universities right today, showing them what to do, and the University of Louisville contract is one of those.

Mr. **Glickman**. Thank you.

Mr. Carney.

Mr. **Carney**. Thank you.

Mr. Zeisloft, you feel that using automotive fuels is a short-term answer to a problem of the nonavailability of aviation fuels, as well as a plus, as you said before, of $300 million in cost to general aviation today. Your organization has evidently done an awful lot of research on this. I am just curious from one standpoint, how are you funding those programs—the research programs?

Mr. **Zeisloft**. Well, our initial program was simply funded out of pocket from the EAA Aviation Foundation, which is a privately funded organization. I would estimate that the costs in the program approached $200,000 in value. We came nowhere near that in actual costs, because a very large portion of it was done by volunteer assistance.

For example, Jim Barton, who is here with us this morning, is our test pilot, and he flew those hours, along with one other man, entirely on a voluntary basis. And incidentally, on this last test, he flew an average of 10 hours a day. And everyone in our organization has attempted to help, because the organization itself is dedicated to the encouragement of personal participation in any phase of aviation, and we want to see the aviation business a healthy, growing thing.

Mr. CARNEY. Now, I am going to ask a very basic question and I perhaps shouldn't ask it in a place called Beech Hall, but what is the difference between av-gas and automobile fuel?

Mr. ZEISLOFT. Well, we used to be smart and tell people about a dollar a gallon, but I am sure you want a better answer than that.

When you put the specifications side by side, you find that there is really very little difference, and the major one is the fact that automobile fuel has deliberately raised volatility to assist engine starting in cold weather. That is primarily because, while an airplane driver like myself is willing to get out and light a fire under the airplane in cold weather to get it started, the average automobile driver is not willing to do that. And so the volatility characteristics are the single biggest difference, technically speaking.

There has been an awful lot of hogwashing through the pages of various publications about these differences. For example, we are told that automobile gasoline is much more susceptible to forming gum than aviation gasoline, and yet when you look at the specifications you find that auto gas is inspected more tightly than av-gas in that particular instance, and the inference is that automobile gasoline is loosely controlled and poorly handled, and that is simply not true.

We have heard many, many comments and still see them, and we will still see them in magazines and papers, saying that automobile gasoline varies all over the map, because literally it does. There are geographic areas and grades of volatility that are scheduled so that in northern Montana in January you get a fuel that has a volatility range that is up at this level, where in Texas in the summertime, you get a volatility level down at this level. So, the trick is to design a fuel system that will handle the total range of volatility and can fly under any conditions—the high volatile winter fuel and southern Texas in summer—if you can figure out how to make that happen.

But that is what we have done. We test it to the most adverse combination of these values, even to going to fuels that were made up deliberately out of volatility limits on the high end to accentuate the problem of vapor lock.

Mr. CARNEY. Why did the aircraft industry design engines that utilized the two varying octane rates?

Mr. ZEISLOFT. Well, I don't think that that was a deliberate kind of operation. There is always an attempt in the aviation industry to get the maximum performance, and I am sure the competitive nature of the business forced people into these different octane levels. The engine manufacturer wanting to sell their engines are faced with the problem of designing an engine that puts out more horsepower for a given pound of weight, and one way of doing that is to raise the compression ratio, and raise along with it the octane requirement. It wasn't unreasonable at the time because the airlines could afford to go along with that, and the military insisted on it.

The real impetus to the octane development, of course, was World War II, where a factor in our fortunate outcome was definitely the fact that we had available high volume, high octane fuel, which gave us about a 20 percent margin in power output of engines. And it was that margin, I think, that was very influential in the Battle of Britain. So it was a kind of development thing that went along with large use of aviation gasoline in the military, and then afterward in commercial aviation. And then the turbines came along and the gasoline usage, that high volume gasoline usage dropped off, and that left personal aviation more or less high and dry on these two fuel levels.

Mr. CARNEY. Thank you.

If I may, Mr. Adkins, I would like to ask your associate a couple of questions, very broad range questions.

The performance of the plane that you have been working with, you say that there has been some degradation in that performance. Could you explain to us precisely what you mean by that?

Mr. MAGRI. Well, in comparing it to the gasoline powered airplane, since we had the reduction in power of approximately 9 or 10 percent, why that is noticable primarily in the takeoff run and climb of the airplane, particularly the weight. We are very heavy with the airplane right now at which we are flying it at.

Mr. CARNEY. Pardon me. You say very heavy?

Mr. MAGRI. The airplane is very heavy. Basically, we took the automotive tank and put them in the airplane, and they are steel tanks. Obviously, for an aircraft application or for the helicopter application, we would use aluminum tanks, which is what you normally do. So the performance has suffered to a certain extent.

Mr. CARNEY. How about range?

Mr. MAGRI. Not as bad. Of course, we are only carrying 36 gallons of methane on board, but I have approximately a 4 hour's range, which is probably 5 or 6 with the normal gasoline system.

Mr. CARNEY. But that is something, if the infrastructure was available around the country, it probably wouldn't bother a lot of people when you are talking about that factor. Is that correct?

Mr. MAGRI. Yes, we do fly quite handily between facilities where we could obtain the methane, no problem there at all. There is enough of it available, if not readily available, but it is available.

Mr. CARNEY. And then on the maintenance side you indicated before that there is a plus factor?

Mr. MAGRI. Yes, you don't have any sparkplug fouling problems at all with the airplane, and the oil stays completely clean, the engine runs strictly clean.

Mr. CARNEY. The weight problem of using methane compared to normal aviation fuel, what would that be?

Mr. MAGRI. Well, if we really designed by using the right tanks, it would probably be an even trade off, but the way we are at this point in time, we have a weight problem because the tests are very preliminary.

Mr. **Adkins**. It would probably be close to 10 percent if we use 5083 series aluminum, because of the fact of the weight, which is 3.5 pounds per gallon versus 6.2 for the aviation gas, and the same is true in automotive systems. For a gallon or for a storage vehicle probably will go down to 10 percent less.

Mr. **Carney**. Now, the ratio that you have talked about, gallon for gallon, was about 1 to 1.3?

Mr. **Adkins**. No, that was for the diesel engine. What we have determined in our flight test work is at economy cruise setting, and at cruise settings, as you see in the information in our statement, is essentially the same. Economy cruise is about nine gallons per hour with av-gas and nine gallons per hour with the methane.

Mr. **Carney**. But it is the takeoff?

Mr. **Adkins**. Strictly takeoff and the time to climb to altitude. If you were carrying the same amount of methane that you were carrying av-gas, your range would be the same.

Mr. **Glickman**. Mr. Adkins, what do you see as the problem involved with the infrastructure or logistics of having the fuel at many GA facilities?

Mr. **Adkins**. It is just going to take time to do it. Right now there are no Government programs that have a sense of urgency to move this along, and it is going to take place in the private sector, and it will only take place in the private sector as people become aware of it, and that is the biggest problem that we have today. The Army's position was we have never heard of it before. If it is so great why isn't someone else doing it?

Mr. **Carney**. It is a matter of the marketplace.

What would it cost a fixed base operator, small town, to install the necessary equipment to provide this type of fuel for his general aviation customers?

Mr. **Adkins**. I can only give you what a filling station would be for a municipal service organization. And a filling station capable of handling about 300 vehicles, it would be in the order of $250,000 to $300,000 and that is the same as it is for CNG systems. In fact, the bid that was submitted to the city of Wichita here by Dual Fuels, was almost identical to the LNG system that we currently have installed out at Northwest Natural Gas right today.

The same would be true with the Army's program at Fort Rucker, except it might be a little bit less expensive, because they will use mobile transporters instead of having a station, so to speak. They will fuel directly out of the tanker trucks, which is what they do right now. So, for aviation fleets, you are talking about, for 150, or if you had an Embry-Riddle Flying School, it easily gets down into under half a million dollars for the total system.

Mr. **Carney**. One last question of you, Mr. Adkins.

What do you see if, again we could go to a hypothetical situation, there was an increase in the utilization of this alternative fuel, what would you see the cost situation being?

Mr. **Adkins**. Again, I rely pretty much on the Government figures, the energy figures, and the Energy Administration and the American gas organization. They have projected figures, including decontrol, and the cost relationship would stay the same through the year 2000 as we have today.

Those are fairly flat figures, and if you refer to that report which came out in 1982, the cost/price relationship between propane, avgas, gasoline, diesel and liquefied methane, it stays approximately the same and we see the only thing that could impact that would be the wide scale implementation of some of the unconventional programs that we are talking about, because then that makes it a very competitive marketplace. Because, with that transport unit that you saw in the slide presentation there, the cost for producing the methane, say, from landfills and the biomass, sewage plants, is only 4½ cents a gallon, so even after you add a profit and everything else.

Mr. CARNEY. That's before the municipality taxes you?

Mr. ADKINS. I think that is right.

Mr. CARNEY. So we are probably now up to 42 cents a gallon; we never knew what value we had in our landfills.

Mr. ADKINS. You have to think about that because the municipality operates it, so whether they tax themselves or not, it's the—it is a tax question, though. That's the same as it is for propane and any of the others. We always have taxes to contend with.

Mr. CARNEY. I appreciate precisely what you are saying. I only added a little back-home humor there.

Mr. Zeisloft, I assume your association is as enthusiastic about the alternate fuels as you are about getting auto gas approved, for FAA approval for the utilization of auto gas in aircraft, is that correct?

Mr. ZEISLOFT. Yes, that's correct.

Mr. CARNEY. And has your organization done any specific types of investigation into other alternatives?

Mr. ZEISLOFT. We are relatively small and we don't have the facilities nor manpower nor capability of carrying out a number of programs together. We have done feasibility type work on alcohols; we have flown aircraft on alcohols, and we have run some ground vehicles on alcohols and, yes, we are very interested in those alternate fuels.

Also, we see this automobile gas as an immediate solution to the problem.

Mr. CARNEY. Well, I thank you very much, all three of you gentlemen, for some very interesting testimony.

Mr. Chairman.

Mr. GLICKMAN. Thank you, Mr. Carney.

One final question, Mr. Adkins. When will the Army, their work program at Fort Rucker, be completed and a decision made as to whether they'll contract with you or anybody else on a larger plan?

Mr. ADKINS. We have got about 50 percent of flight test time which will, continue, right after Labor Day, and we should be finished by the middle of October. And then they'll go through the data analysis, and we are carrying on discussions right now with the Army, planning personnel, on establishing budget in the fiscal year budgets for, which is quite late, but they have means of doing that.

This is a concept evaluation process that we are involved in, so it gives them certain leeway as far as planning.

Their plans, the Army's plans, are to go forward to the Chief of Staff's office, Army Chief of Staff's office, with a recommendation based on those test results, and I think that we'll probably see that go forward the early part of next year.

Mr. GLICKMAN. Again, we thank you both, or all three of you, for excellent testimony.

Our next panel is our panel II, William Paynter, president of Union Flights, Sacramento, and I think that Mr. Paynter came a long way and we appreciate that, and you brought some other witnesses with you.

Then we have Mr. Robert Donahue of the Illinois Department of Transportation, and Dr. Max Shauck, I think, of Baylor University, Waco, Tex.

Why don't all three of you gentlemen go up to the witness table and all three of you gentlemen brought demonstration airplanes, which I know that we'll be looking at after we finish our hearing today.

Mr. DONAHUE. Mr. Chairman, if I may, Mr. Larry Platt, who is chief of the bureau of aircraft maintenance for the State of Illinois.

Mr. GLICKMAN. It's a pleasure to have you, Larry. You may proceed.

As I mentioned to the other witnesses, you may feel free to summarize your testimony if you wish to in order to expedite matters.

Why don't we go ahead and proceed as we have, and we'll go first with Mr. Paynter, then with Mr. Donahue, and then with Dr. Shauck.

Mr. Paynter, why don't you go ahead?

STATEMENT OF WILLIAM C. PAYNTER, PRESIDENT, UNION FLIGHTS, SACRAMENTO, CALIF., ACCOMPANIED BY GORDON COOPER, TECHNICAL CONSULTANT; ROBERT L. DONAHUE, DIRECTOR, DIVISION OF AERONAUTICS, ILLINOIS DEPARTMENT OF TRANSPORTATION, SPRINGFIELD, ILL., ACCOMPANIED BY LARRY PLATT, CHIEF, BUREAU OF AIRCRAFT MAINTENANCE FOR THE STATE OF ILLINOIS AND DAVID LEWIS, DEPUTY DIRECTOR; AND DR. MAX SHAUCK, BAYLOR UNIVERSITY, WACO, TEX.

Mr. PAYNTER. Thank you, Mr. Glickman, for the opportunity of appearing here today.

I brought a couple other gentlemen with me. It took all of us to get here.

We had to bring the fuel with us in a truck because we found that methanol can't be supplied by local operators because they can't be depended upon to keep it pure. We found a lot of fuel contamination.

Gordon Cooper, who is my associate, and I traveled all over the United States within the same plane.

Mr. GLICKMAN. You were in Washington, weren't you? I recall that there was some publicity.

Mr. PAYNTER. Yes, sir, we were, and we found that we had monumental problems with contamination; no trouble with the airplane; no trouble with the consumption of the fuel, but problems with the handling of this fuel.

So I brought Dick Calkins with me, who is a retired brigadier general from the California National Guard, who used to fly Governor Brown and Governor Brown, Sr., and Governor Knight before him.

And I brought Tom with me, another one of my associates, and he worked with me for the telephone company, and he was also in the Air Force. So it took all of us to bring the airplane here.

Mr. GLICKMAN. We appreciate the fact that it was not an easy task, and the committee believes the subject matter is important enough that it was significant that we have the opportunity to actually visually see what you were doing.

Mr. PAYNTER. Thank you.

I became interested in an alternative fuel for aviation, just out of desperation, in 1973 when we had the Arab oil embargo.

I could see the price of aviation fuel going completely out of sight, and that opinion was justified.

The airlines, in 1972, the total cost of operation of the airlines in this country was $10.6 million. That included everything; depreciation, people, fuel, management, everything.

In 1982 the airlines flew less hours and spent $11 billion on fuel alone. Now, that's pretty appalling.

However, as a private operator and as a general aviation operator, I was faced with the same thing.

We forecast, for a Piper Super Cub, $2 an hour fuel costs back in the fifties. It had already passed $15 an hour when I lost our biggest customer simply when he told us he couldn't afford us any more. So we had to do something.

Our jet we bought for the State of California, and I was fortunate in flying the President for a couple of years while he was Governor of California, we forecast $33.66 for our cost of fuel for the Citation jet, and that worked out perfectly until about 1975, and then it began to escalate.

And when we finally leased the jet to a company in Canada, it had already passed $300 an hour for the cost of fuel, so the customer is simply telling general aviation it lost.

And as far as the private man that used to go out in the airplane and fly over to Jonesie's in Napa for lunch, he no longer can afford to do that. Their airplanes are sitting on every airport, tied down, they haven't even moved, some of them, for a year at a time.

We became interested in putting this fuel in the field simply because we feel that if for no other reason than to keep them honest, the oil companies, and OPEC, need a little competition.

We found this fuel to be very effective. We have been delighted with all the tests we have run on it.

We have put a Piper Super Cub in the field, and with very minor modifications we did what we could to protect it against erosion. We increased the fuel flow for takeoff, and advanced the spark. Other than that, we did nothing.

So far our fuel consumption has been 1.2 to 1.3 times greater than it was on gasoline; however, we found some fantastic spinoffs for one thing.

We have flown it 300 hours on alcohol fuel and we did a compression check before we came on this flight, and it's 80/79 compression. That's new specifications on the engine.

We started with a freshly overhauled engine and there is no sign of any wear at all in it so far, and we boroscoped the engine repeatedly, look down through the sparkplug holes, and find nothing down there.

There is no pitting, no problems, so we haven't found a water factor to be excessive. To the contrary, we found it to be less.

We know it's not as polluting in the atmosphere. It comes from an inexhaustible source and the Arabs can't shut it off.

We are paying at the present time 70 to 90 cents a gallon in bulk for the fuel at the pump in Sacramento. You can buy it from the hot rod shops and it costs $1.30 a gallon, which is as cheap or cheaper than gasoline out there, so we haven't found those costs to be excessive.

We find that most of the reasons for objecting to the use of alcohol fuel is just plain prejudice. People aren't used to the idea, and even when you bring it to them and tell them what you are doing, and arrive somewhere with an airplane that's operating on the alcohol fuel, we have had people actually come over to us and say, you fellows realize you can't do this, don't you. Now, that's amazing. It reminds me of the guy that can look through a keyhole with both eyes.

I'm only saying that we don't know all the answers yet, but we certainly have no intention of giving up, and so far we are getting just as good use out of that, as you'll see when we fly the airplane after a while, as we ever got out of it on gasoline.

I think I've covered just about everything.

[The prepared statement of Mr. Paynter follows:]

TESTIMONY TO BE DELIVERED TO ALTERNATIVE AVIATION FUELS SUBCOMMITTEE CHAIRED BY THE HONORABLE DAN GLICKMAN IN WICHITA, KANSAS 29 AUGUST 1983

Mr. Chairman, Members of the Panel, Ladies & Gentlemen:

My name is Bill Paynter. I am President of Union Flights of Sacramento, California, and Board Chairman of Alcohol Aviation Fuels, Inc. I wish to take this opportunity to thank you for the invitation to testify before this panel today and to display, and fly, our alcohol powered Piper Supercub for you. It would also be appropriate to thank R. L. (Dick) Calkins and Tom Livingstone who volunteered their time to help in flying our aircraft and driving the support truck which brought the alcohol fuel from Sacramento to Wichita. We also wish to thank Celanese Chemical Company for sponsoring our trip here and for the confidence in our project which prompted them to do so.

Ladies and Gentlemen, aviation is a fuel intensive industry, as is all of transportation. The price of fuel is directly reflected in the cost of our product to the consumer. To illustrate, I will use my own small company which owns less than thirty airplanes. (Union Flights business is to provide aircraft and aviation services to other companies who for one reason or another do not wish to own and operate their own flight departments.) A careful study is done on each aircraft to determine acquisition and operating costs (which vary widely) in arriving at lease or charter rates to our customers. Piper supercub patrol airplanes which sold (new) in 1972 for less than $20,000.00, now are priced at $45,000.00. A Cessna Citation Jet which we purchased (new) in 1972 for $730,000.00 is now priced at $1,800,000.00. Aviation gasoline in 1972 was priced at 28¢ per gallon and jet fuel was 21¢. Jet fuel and avgas now average near $2.00 per gallon. It doesn't take much of an expert to see that while related costs (excluding taxes and regulation costs) have increased by 100-300%, fuel costs have escalated by 600-900%. The scheduled air carriers total cost of operation, i.e. amortization, depreciation, fuel, oil, maintenance, personnel, insurance, taxes, etc. was $10.6 billion in 1972. In 1982 fuel alone cost $11 billion. The Arab oil embargo in 1973 was the beginning of a syndrome which can only end in disaster to transportation in general and to aviation in particular. Without transportation, America is out of business. We are sending $80 billion + per year to the middle east to load our atmosphere with hydrocarbons because we have been led to believe that that is the only fuel we can use when in truth we are up to our necks in the raw materials from which to produce a fuel which would leave our air clean and which would never run out.

Our total dependence on petroleum as an energy source has placed us in a very vulnerable position since a large percentage of world oil reserves are located in the middle east. Our failure to develop a viable alternative fuel has delivered to one industry (oil) and a few foreign nations a virtual license to hold hostage the entire transportation system and to threaten to cripple our national defense facilities in the event of an emergency.

It is our belief, and that of the witnesses here today, that properly developed and formulated alcohol fuel is equal, and in many cases superior, to hydrocarbon fuel in performance. We also find it safer to use and to handle than petroleum based fuels. Alcohol fuel can be produced here in America in unlimited quantities from renewable sources. We are proving that it does not pollute the air, materially reduces engine wear, costs half as much, and that it cannot be turned off by the Arabs or the Russians.

Detractors and status quo advocates are constantly using the fact that alcohol contains half as many BTU's (British Thermal Units) per gallon as hydrocarbon fuels so therefore an engine will either use twice as much alcohol or that it will only develop half as much power - Right? Wrong! The BTU theory is great if you are building a fire but if you are talking about the ability of an engine to extract power from a fuel it becomes a question of thermal efficiency. We are working with engines which were designed to use gasoline and kerosene and finding cost and efficiency figures to be comparable. Engines designed for alcohol fuels now in prototype and design stages will outperform hydrocarbon fueled engines in every regime. The same detractors and "you-can't-get-there-from-here" types will announce loudly that this fuel burns with no visible flame - therefore it's dangerous! Perhaps that's why gasoline is outlawed at Indianapolis and methanol rules the roost. Bobby Unser, during testimony before a Senate Energy Subcommittee hearing chaired by Senator John Glenn in Washington in early 1981 showed film clips of two identical major crashes in which he was involved. Gasoline was the fuel in the first, alcohol in the second. In the first crash, Unser received major burns (the wreck resembled a giant fireball) and he walked away from the second.

Alcohol fires can be extinguished easily with water, which aggravates a gasoline fire. As for the invisible flame objection, fuel additives can render the flame visible.

At the turn of the century, Henry Ford's horseless carriages were operating very successfully on alcohol fuel and he was touting alcohol as being the fuel of the future. John D. Rockefeller owned a gaggle of real estate with oil flowing from it and Ford found himself stuck with gasoline. Alexander Graham Bell wrote in 1907 that alcohol was the fuel of the future. It's an old fuel.

The allies, following the destruction of the Ploesti Oil installations by our bombers were astounded to find fighters continuing to operate on synthetic (alcohol) fuel. Only massive raids on such things as ball bearing plants and depletion of trained people brought Hitler's machine to its knees. In 1945 a group of energy experts were dispatched to a defeated Germany by the president. The mission was code named T.O.M. (Technical Oil Mission). The purpose was to investigate Germany's use of alternative energy to continue to operate in the face of a thrust which would be fatal to us today. The T.O.M. people found a virtual treasure trove of information in the I. G. Farben building in Frankfurt which the German scientists had been ordered to destroy but which they had failed to do. The materials were packaged, some were microfilmed, all were divided among several groups including the Library of Congress, the National Archives, Texas A & M University, Stanford and various private collections. In 1947 and 1948 pilot plants were established at Louisiana, Missouri and by 1951 these plants were producing 200 - 400 barrels per day of synthetic fuel using the German Berguis and Fischer-Tropsch processes. The plants were operated by the U. S. Bureau of Mines. (The Germans produced twenty five million barrels of fuel from coal in 1943 alone, from January 1938 to March 1945 the Germans produced 127,357,000 barrels of synthetic fuel.)

The American Louisiana, Missouri pilot program was destroyed in its entirety several years ago and most of the records met a like fate because the U. S. Government was considered to be competing with private enterprise in the energy field. In other words: The technology to have rendered the present energy crunch, exorbitant fuel prices, international blackmail, and possibly even the threat of World War Three impotent was handed to us as one of the spoils of war and we blew it.

There is nothing wrong in the energy and transportation fields that a little competition in the form of an alternative fuel won't cure. We have found our piper cub project to have demonstrated that alcohol fuel is equal to or better in all ways to hydrocarbons. This is the country which gave the world the airplane (also the automobile) and forever changed our way of life. We didn't become the greatest country on earth by learning to live with problems. We've solved them. Let's solve this one. We are convinced that we can save the aviation industry, but first we have to get the government and the manufacturers to recognize that the reason they are closing plants and suspending production is that they, and we, are pricing ourselves out of business. The high prices of equipment are bad but the cost of energy is a disaster.

Thank you Mr. Chairman, members of the panel and ladies and gentlemen.

Bill Taylor

Mr. GLICKMAN. I'll not try to look through a keyhole unless I have an eye patch on.

Mr. Donahue, it's a pleasure to have you here.

Mr. DONAHUE. Thank you, Representative Glickman. I appreciate it.

My prepared remarks are relatively short and if you'll bear with me, I'll go through and just read the prepared remarks.

Mr. Chairman, I am Robert L. Donahue, Director of Aeronautics for the Illinois Department of Transportation.

I would like to thank you and the committee for asking us to be here today to testify about our aviation alcohol fuel project.

We are very enthusiastic about this project and appreciate the opportunity to share our experience with you.

The State of Illinois is vitally interested in the development of ethanol as one alternate to fossil fuels.

The State is interested in ethanol fuel for three reasons:

First, as a leading agricultural State, Illinois is always seeking new and expanded markets for our agricultural commodities. Success in this effort directly improves the economy of Illinois. Success also reduces crop surpluses and, therefore, the need for costly Federal subsidy programs.

The second reason for Illinois' interest in ethanol is the need for a reliable source of fuel. The last decade has demonstrated conclusively that the United States should reduce its reliance on foreign energy sources.

Foreign oil is subject to supply disruptions and price shocks, which can have a negative effect on our economy.

In contrast, the American farmer has a proven record of reliability in meeting the needs of our Nation and the world. Ethanol is a reliable source of fuel in a much more fundamental sense as well.

It is renewable. Every barrel of oil we remove from the ground leaves us with smaller reserves for the future.

However, whatever agricultural commodity, byproduct or waste is being used to produce ethanol, there will be another crop next year.

The third reason for our intense interest in ethanol is environmental improvement burning ethanol produces far fewer hydrocarbon emissions than gasoline. By using ethanol, we can improve air quality at low cost and without reducing personal mobility.

For these three reasons, the State of Illinois has an aggressive program to promote ethanol fuel. I would like to briefly mention five aspects of this program.

State vehicles use ethanol-enhanced gasoline. Since 1980, all 9,500 State-owned vehicles have used a blend of 90 percent gasoline and 10 percent Illinois-produced ethanol.

The name of that, of course, when it was started, was gasohol. Some vehicles have been converted to 100 percent ethanol.

Since 1977 the Department of Transportation and Department of Central Management Services have experimented with ethanol in passenger vehicles, vans and trucks; 11 vehicles have now logged 211,000 miles in routine use with excellent performance.

The State will soon produce ethanol. The Illinois Department of Corrections will operate a 500,000 gallon per year ethanol distillation plant to provide ethanol for use in the State's vehicle fleet. This plant is linked to an innovative hydroponics and aquatic biology program to use byproducts, such as the warm thin stillage and carbon dioxide for food production. State grants support ethanol research and development.

The State's alternate energy bond program has provided over $550,000 to five projects for research and development in ethanol production and consumption technology.

A State-owned aircraft is successfully flying on ethanol. For the last 6 months, the Illinois Department of Transportation has operated a Cessna 182 with a Continental O-47OU engine on 190-proof ethanol. This engine, you know, has an 8.7 to one compression ratio.

The fifth element of our program is the focus of my testimony today. The conversion of the Continental engine from gasoline to 190-proof ethanol was remarkably simple and inexpensive.

We selected 190-proof ethanol rather than 200-proof for demonstration purposes, since the equipment necessary for its production is less expensive and more widely available.

Four simple modifications were necessary.

First, the weight of the float in the carburetor was adjusted to compensate for the difference between the specific gravity of ethanol and that of gasoline.

Second, the diameter of the fuel jets in the carburetor was increased by 30 percent.

Third, the magneto timing was advanced by 8 degrees to fire the sparkplug earlier in each cycle.

Fourth, based on flight experience, we installed a preheater to bring the alcohol to 155, 167 degrees Fahrenheit before it enters the carburetor.

We have now logged 66 flight hours in alcohol-fueled aircraft. Our experience in a number of key areas is as follows:

Fuel efficiency: In a controlled side-by-side test at altitudes below 5,000 feet, a gasoline-powered Cessna 182 consumed 12.5 gallons per hour compared to 14.5 gallons per hour using ethanol. We believe that at higher altitudes the difference will diminish and that an engine designed for the burning characteristics of alcohol will be substantially more efficient.

Performance: We have achieved a small improvement in performance on ethanol. Approximately 5 percent more power is available at takeoff.

Economy: The division has been purchasing 200-proof ethanol for approximately $1.80 per gallon and diluting it with 5 percent distilled water to obtain 190-proof ethanol.

The effective cost is therefore $1.71 per gallon, which compares favorably to $1.90 to $2.10 for av-gas. The lower cost of ethanol compensates for reduced mileage.

Engine wear: It is still too early to fully determine the effect of ethanol use on the engine. However, all signs are positive.

We have noted a substantial reduction in carbon deposits in the oil, which should lead to reduced friction and wear.

In addition, the operating temperature of the engine has been reduce 125 degrees, which should result in less engine fatigue.

The Quality control: Controlling the quality of ethanol is much easier than for gasoline. The only necessary tests are to check the alcohol content, using a hydrometer, and to check the alkalinity, using litmus paper. We then filter the fuel through a 10-micron filter to remove any impurities. This process has insured quality fuel without the complex testing necessary for aviation gas.

Safety: We have had no fuel-related safety problems with the ethanol-powered aircraft thus far. In fact, one major safety concern with gasoline is nullified by use of ethanol. Unlike gasoline, ethanol mixes with water and, therefore, small amounts of water in the fuel will not cause engine failure.

All in all, the experience of the Illinois Department of Transportation, with ethanol as a fuel for aviation, has been excellent. The viability of ethanol as an alternative to aviation gasoline in piston engines has been demonstrated. Much more work needs to be done. And while our resources are limited, we wish to be active participants in the process.

As we continue our program, we plan to obtain a supplemental type certificate from the FAA for ethanol, both for the Continental engine and the Cessna airframe. By obtaining an STC, we will remove the use of ethanol from an experimental status, which will allow other aircraft operators to convert to ethanol.

As a second phase, we hope to be able to demonstrate the viability of ethanol as an alternative to jet fuel in turboprop aircraft. Doing so would dramatically increase the market for ethanol and encourage its availability on a retail commercial basis.

Given the potential for ethanol as a renewable, domestically produced, nonpolluting, and efficient fuel, the Federal Government should take a more active role in demonstrating its practicality and promoting its use.

An expanded Federal effort with respect to ethanol promotion can be expected to have an immediate, substantial and long-range impact on resolving our Nation's energy and economic problems.

In closing, I would just like to say that we flew here in our ethanol-powered aircraft and that it is available for your inspection. I will be glad to answer any questions about the aircraft or the ethanol project in general.

Thank you again for the invitation to testify today about the success we in Illinois have had with our ethanol-fueled aircraft.

[The prepared statement of Mr. Donahue follows:]

TESTIMONY BEFORE THE
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
BY ROBERT L. DONAHUE
DIRECTOR OF AERONAUTICS
ILLINOIS DEPARTMENT OF TRANSPORTATION
WICHITA, KANSAS
August 29, 1983

Mr. Chairman, I am Robert L. Donahue, Director of Aeronautics for the Illinois Department of Transportation. I would like to thank you and the Committee for asking us to be here today to testify about our aviation alcohol fuel project. We are very enthusiastic about this project and appreciate the opportunity to share our experience with you.

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The second reason for Illinois' interest in ethanol is the need for a reliable source of fuel. The last decade has demonstrated conclusively that the United States should reduce its reliance on foreign energy sources. Foreign oil is subject to supply disruptions and price shocks which can have a negative effect on our economy. In contrast, the American farmer has a proven record of reliability in meeting the needs of our nation and the world. Ethanol is a reliable source of fuel in a much more fundamental sense as well. It is renewable. Every barrel of oil we remove from the ground leaves us with smaller reserves for the future. However, whatever agricultural commodity, by-product or waste is being used to produce ethanol, there will be another crop next year.

The third reason for our intense interest in ethanol is environmental improvement. Burning ethanol produces far fewer hydrocarbon emissions than gasoline. By using ethanol we can improve air quality at low cost and without reducing personal mobility.

For these three reasons the State of Illinois has an aggressive program to promote ethanol fuel. I would like to briefly mention five aspects of this program.

1. State vehicles use ethanol-enhanced gasoline. Since 1980, all 9500 state-owned vehicles have used a blend of 90 percent gasoline and 10 percent Illinois produced ethanol.

2. Some vehicles have been converted to 100 percent ethanol. Since 1977, the Department of Transportation and Department of Central Management Services have experimented with ethanol in passenger vehicles, vans and trucks. Eleven vehicles have now logged 211,000 miles in routine use with excellent performance.

3. The state will soon produce ethanol. The Illinois Department of Corrections will operate a 500,000 gallon per year ethanol distillation plant to provide ethanol for use in the state's vehicle fleet. This plant is linked to an innovative hydroponics and aquatic biology program to use byproducts such as the warm thin stillage and carbon dioxide for food production.

4. State grants support ethanol research and development. The state's alternate energy bond program has provided over $ 550,000 to five projects for research and development in ethanol production and consumption technology.

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As we continue our program, we plan to obtain a Supplemental Type Certificate (STC) from the FAA for ethanol, both for the Continental engine and the Cessna airframe. By obtaining an STC, we will remove the use of ethanol from an experimental status which will allow other aircraft operators to convert to ethanol.

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Given the potential for ethanol as a renewable, domestically produced, non-polluting and efficient fuel, the federal government should take a more active role in demonstrating its practicality and promoting its use. An expanded federal effort with respect to ethanol promotion can be expected to have an immediate, substantial and long-range impact on resolving our nation's energy and economic problems.

In closing, I would just like to say that we flew here in our ethanol-powered aircraft and that it is available for your inspection. I will be glad to answer any questions about the aircraft or the ethanol project in general. Thank you again for the invitation to testify today about the success we in Illinois have had with our ethanol-fueled aircraft.

Mr. GLICKMAN. Thank you very much.

Dr. Shauck, we now come to you and we appreciate you being here, and why don't you go ahead and proceed.

Dr. SHAUCK. Mr. Chairman, I appreciate the opportunity to participate in today's hearing. I feel we are involved in an undertaking which will prove to be of critical benefit to both the economic strength and security of our country.

I would like to just briefly sketch why I feel that ethanol must be considered very seriously by the aviation community at this time.

In the last 18 months, I have flown a Bellanca Decathalon over 400 hours on 100 percent ethanol.

The modifications to the aircraft are extremely simple. I did almost all the mechanical work myself. I mention this and the fact that I'm not an aircraft mechanic simply to emphasize the simplicity of the modifications.

Fact: The aircraft flies and flies well on a fuel which is easily made from materials which for all practical purposes are infinitely renewable and domestically available in abundance.

I should really stop at this point because this single fact far outweighs the significance of the remainder of my testimony, at least in my view.

Fact: Not only are the feedstocks for the alcohol domestically available, they are available in every State in many forms.

December and January of last winter, we undertook a transcontinental flight for the purposes of demonstrating the feasibility of ethanol-powered flight under the auspices of the National Aeronautics Association.

I stress the word "feasible." I would like to read the wording on the Certificate of Record awarded by the NAA, "This Certificate of

Record is awarded * * * for the first transcontinental flight made on locally produced renewable aviation ethanol fuel."

Locally produced and renewable. Add to that easily produced. Maybe almost folklore easy, Snuffy Smith and the revenuers, an American tradition.

In Texas, fuel is produced from waste candy; in New Mexico, fuel is produced from milo; in California, from cold oranges; in Arkansas, from rice; in Georgia, from the rejections of a peppermint plant.

On other flights, Kansas wheat, Iowa corn, Illinois corn, from waste such as cheese whey in Wisconsin.

I could give you a very long list of existing and potential feedstocks.

Suffice it to say, we have not begun to tap our potential feedstocks for producing alcohol fuel.

Fact: This is not an alternate fuel. It is a superior fuel.

In June 1982, here in Wichita, we conducted power tests for our application to the FAA for certification of ethanol as an aircraft fuel, at Javelin Aircraft under carefully controlled conditions.

Incidentally, we used locally produced wet alcohol for part of the test. The ethanol produced 3 to 5 percent more power than aviation gasoline at comparable power settings. It burns cooler in the engine, which will extend engine life, and it burns cleaner inside and outside the engine. If a large portion of our transportation fleet were powered on ethanol, it would result in a dramatic improvement in the air quality of our cities.

It is economical now. I fly at current wet ethanol price for 180-proof ethanol for 2 to 3 cents a mile cheaper than on aviation gasoline. This can be improved.

We know we can improve the efficiency of aircraft engines running on alcohol to equal the mileage on gasoline, because the same thing is being done with automobile engines. Then the direct operating costs will be approximately one-half those of aviation gas.

I have flown this aircraft on about 40,000 miles, most of it cross country at air shows, in aerobatic demonstrations, at high altitudes, which in this case is 15,000 feet, and the only problems which occurred have been easily solved.

I'd like to address briefly the implications to a smaller segment of our society than the broad implications for the farm situation and the balance of trade payments. The people who fly, either professionally or for the love of it, or as quite often is the case, both, the acceptance of ethanol by the FAA as an aviation fuel, after appropriate testing, will mean that the general aviation pilot once again can look forward with confidence to an assured supply of affordable fuel. That is not the case now.

For these reasons, I believe that the appropriate committees in the Congress should consider the ways and means to help speed up this process of certification of an aviation fuel we desperately need at this time.

Thank you.

[The prepared statement of Dr. Shauck follows:]

STATEMENT OF DR. MAX SHAUCK

Mr. Chairman:

I appreciate the opportunity to participate in today's hearing because I feel very strongly that we are involved in an undertaking which will prove to be of critical benefit to both the economic strength and security of our country.

I would like to briefly sketch for you why I believe that ethanol (grain-based alcohol) must be considered very seriously by the aviation community now and soon by all sectors involved in transportation.

In the last 18 months I have flown a Bellanca Decathlon over 400 hours on 100 % ethanol. The modifications to the aircraft were extremely simple. I did almost all the mechanical work myself. I mention this and the fact that I am not an aircraft mechanic simply to emphasize the simplicity of the modifications.

FACT # 1 - The aircraft flies and flies well on a fuel which is easily made from materials which are for all practical purposes infinitely renewable and domestically available in abundance. I should really stop at this point because this single fact far outweighs the significance of the remainder of my testimony, at least in my view. Unfortunately brevity is not the hallmark of one who earns his livelihood lecturing to college students.

FACT # 2 - Not only are the feedstocks for the alcohol domestically available, they are available in every state in many forms. December and January of last winter we undertook a transcontinental flight for purposes of demonstrating the feasibility of ethanol powered flight under the auspices of the National Aeronautics Association (N.A.A.). I stress the word feasible. I would like to read the wording on the Certificate of Record awarded by the N.A.A.: "This Certificate of Record is Awarded to Max Shauck as Pilot of The First Transcontinental Flight Made on Locally-Produced Renewable Aviation Ethanol Fuel."

Locally-produced and renewable. Add to that easily produced. Maybe almost folk-lore easy. Snuffy Smith and the "Revenoors" - an American tradition of know-how which we have heard lately lamented for its demise. I mean, of course, lamenting the supposed demise of know-how and industry, not the moonshine industry.

In Texas, fuel produced from waste candy; in New Mexico, fuel produced from milo; in California - from culled oranges; in Arkansas - from rice; and in Georgia - from the rejections from a peppermint plant. On other flights: Kansas - wheat; Iowa - corn; Illinois - corn; and from waste such as cheese whey in Wisconsin. I could give you a very long list of existing and potential feedstocks. Suffice it to say, we have not begun to tap our potential feedstocks for producing alcohol fuel.

FACT#3 - This is not an alternate fuel, it is a superior fuel. In June 1982, here in Wichita, we conducted power tests for our application to the F.A.A. for certification of ethanol as an aircraft fuel at Javelin Aircraft under carefully controlled conditions.

Incidentally, we used locally produced "wet" alcohol for part of the test. The ethanol produced three to five percent more power than aviation gasoline.

It burns cooler in the engine which will extend engine life, and it burns cleaner inside and outside the engine. If a large portion of our transportation fleet were powered on ethanol, it would result in a dramatic improvement in the air quality of our cities.

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I have flown this airplane on ethanol on transcontinental flights, in aerobatic demonstrations at some of the largest and some of the smallest airshows in the country, and in high altitude tests, and the only problems which occurred were those which have been easily solved.

I will not go into the economic benefits to the farmers and the balance of payments situation. I think they are obvious and have been or will be brought out in other testimony.

I would like to address the implications to a smaller segment of our society...... the people who fly either professionally or for the love of it, or as is quite often the case, both.

I believe the acceptance of ethanol by the F.A.A. as an aviation fuel after appropriate testing will mean that the General Aviation pilot once again can look foreward with confidence to an assured supply of affordable fuel. That is not the case now.

For these reasons I believe that the appropriate committees in the Congress should consider the ways and means to help speed up this process of certification of an aviation fuel we desperately need at this time.

Thank you.

Mr. GLICKMAN. Thank you for your excellent testimony and also providing us an opportunity to look at the airplane. Let me just ask you a few basic questions.

I want—Mr. Paynter talked about methanol, Mr. Donahue talked about ethanol, and I wonder if you might talk a little bit about the differences between the two and how they interrelate in terms of operating fuel for an airplane.

Mr. Paynter, why don't you begin.

Mr. PAYNTER. Ethanol comes from the food chain; and it's alcohol that you drink

Mr. GLICKMAN. Not right now.

Mr. PAYNTER. Methanol is poisonous, and it is a cellulose product arrived at generally by distillation. It can be produced from anything that ever grew under the Sun, including the same things that produce ethanol. The story that gets around is that ethanol—the President made this statement and it appalled me, and I'm sorry that he didn't know better than to say this—but he mentioned—the press asked about what—what is being done about alcohol fuel in the United States. He said, well, we are not concentrating on that any more because we would be forced into taking a choice between fuel and food.

Well, nothing could be further from the truth, because after the alcohol is extracted, in the case of ethanol, for Bob and Max—after the alcohol is extracted from the food material, the protein is still all there and you can make cereal out of it, you can make dog food, cat food, and cattle food, all kinds of things out of it, so that's not true. And, as I said, I think the President should have been informed of that.

Mr. GLICKMAN. Now, in terms of operating an aircraft on methanol versus ethanol, I assume that there is some chemical differences between the two. Are there? And what are they?

Mr. PAYNTER. I was going to say we have flown our airplane on both ethanol and methanol. Essentially, as Bob pointed out, the changes that you make in the airplane and in the engine are almost identical, and we didn't find any real difference. The ethanol performed every bit as good as the methanol did, so we are no longer referring to methanol aviation fuel; we are referring to it as alcohol aviation fuel.

Mr. DONAHUE. I think that's very, very important, because I don't think that either Bill, Max, or I are here to toot the relative merits of either ethanol or methanol or put them one in competition with the other. We are really here to show that there are viable areas of alternate fuels from renewable sources. The waste stream that would produce methanol, the waste stream that can produce ethanol, is rampant in the United States and is certainly not utilized.

Mr. GLICKMAN. But what I'm trying to get at is that they are in a sense interchangeable?

Mr. DONAHUE. Absolutely.

Mr. GLICKMAN. For the purposes, I think, Dr. Shauck, you indicated that you flew on what? Did you fly using ethanol?

Dr. SHAUCK. Yes, sir.

Mr. **GLICKMAN.** Do you use methanol in your engine without any modifications in the engine, or would you have had to make some modifications?

Dr. **SHAUCK.** Well, since Bill has flown on ethanol, I assume I could fly on methanol. I haven't done it. I'm sure it's the same.

Mr. **PAYNTER.** I'm sure you could.

Mr. **GLICKMAN.** What about the price difference between the two? That's where there may be some difference, I assume.

Dr. **SHAUCK.** Well, there is an important fact here. In the case of ethanol fuel, we pay $1.30 a gallon for 180-proof ethanol. But the technology for the production of ethanol is basically in its infancy. I think we are—we have heard rumors in the industry and we have some concrete examples of breakthroughs in the technology which would bring the cost down probably to about $1 a gallon.

Mr. **GLICKMAN.** You say $1.30 for what?

Mr. **SHAUCK.** Wet ethanol, which is the 180-proof.

Mr. **GLICKMAN.** And what are you paying, Mr. Paynter? I forgot. You said earlier in your testimony.

Mr. **PAYNTER.** In bulk, we are paying anywhere from 70 to 90 cents. We are buying 500 to 1,000 gallons at a time. However, at the pump in the speed shops in California, at least, you can buy it for $1.30 a gallon.

Mr. **GLICKMAN.** Mr. Carney, you wanted to ask a question?

Mr. **CARNEY.** Mr. Donahue said he was paying $1.91, I think you said.

Mr. **DONAHUE.** We are buying dry alcohol, 200-proof, and diluting it down.

Mr. **GLICKMAN.** Let me ask you this: The issue of interchangeability of fuels is one that is—I'm very interested in. Once an aircraft is modified to handle the alcohols, can different fuels be used interchangeably?

Now we have basically said here the alcohols can be used interchangeably. What would be the possibility of—if you go back to your auto gas or av-gas, what would you need to do, and can you use a combination of the two? Could you mix them interchangeably? Let's say you could; you have a switch on the airplane that could go from one over to the other. How could one do this?

Mr. **SHAUCK.** You don't even need a switch. You simply lean the engine out using the manual mixture control. And I think all of us have experienced this. You simply mix gasoline—if you cannot—if you run out of the availability of alcohol, it's no problem whatsoever.

Mr. **GLICKMAN.** Any other comments on my question?

Mr. **PAYNTER.** I think—I haven't tried burning gasoline because it would destroy the validity of the testing. We are trying to—we are trying to prove something here, and I want to go through a full overhaul period with our little engine that we are using. I want to go through a full overhaul period so we can tear the engine down at the end of 2,000 hours and compare it directly with what we know we find with hundreds of overhauls on the same engines.

Mr. **GLICKMAN.** Mr. Donahue?

Mr. **DONAHUE.** I would think, Mr. Glickman, that with the compatibility between methanol and ethanol, that we need to get more into the technology. It's possible that these alcohols can be mixed, and this would be no more unusual to have it fueled on alcohol or on liquid methane or liquid hydrogen, if you will, than it is to pull into a gas station and buy regular gas or premium gas or buy diesel fuel.

Mr. GLICKMAN. Well, I guess what I'm trying to get at is—going to the aggregate problem—is, you know, potential fuel problems. It would be nice to see aircraft developed that have interchangeability characteristics so you could run on the alcohols or you could run on the gasoline, either auto or aviation gas, or in mixtures thereof; you know, give the operator that kind of flexibility. And I'm just wondering whether you think we can reach the point where we'll have that kind of capability.

Mr. PAYNTER. I believe so. I think we are already well along. In fact, Gordon Cooper has an engine that can sense what fuel is in it and make the necessary adjustments electronically.

Mr. GLICKMAN. Let me go to another issue now, which is the issue of jet fuel and fuel for turboprop aircraft. One of you mentioned this before. Let me know, what do you think about the use of the alcohols in this area?

Mr. DONAHUE. What we would like to—I think I did mention that, Mr. Chairman, is what we would like to do as a part of our ongoing program with the turbine engine. We'd like to get into a program with, for instance, the University of Illinois, where using their dynamometer we could start to blend ethanol with—or methanol with—JP and check the outcome of the power based on dynamometer readings as we progress into adding a greater and greater percentage of alcohol.

Mr. GLICKMAN. Has any of this work been done to date that you are aware of?

Mr. DONAHUE. I think Pratt and Whitney has done some on it.

Mr. PAYNTER. So has GE.

Mr. GLICKMAN. Are they mixable?

Mr. DONAHUE. Ethanol——

Mr. GLICKMAN. And JP.

Mr. DONAHUE. It has to be 200-proof. It cannot be—it cannot be anything less than the neat, the 200-proof dry alcohol. That's what the technology shows us so far.

Mr. GLICKMAN. But to date nobody is in fact flying any such aircraft?

Mr. DONAHUE. No.

Mr. GLICKMAN. OK. Let me ask you a question regarding flammability. It's come to my attention that one of the performance characteristics of an alcohol-fueled airplane is that it does not have a visible flame and therefore if a fire developed you would not see it or know where it was coming from, which is a potential safety problem.

I wonder if anybody might want to comment on that?

Mr. PLATT. Through our testing I have had several fires, and also I have initiated several fires just to disprove that, and with the ethanol the flame is visible, and in any shaded area it is more visible. Methanol has a little lack of flame, as you'll see if you have ever watched the Indianapolis races. This can be easily eliminated if anyone feels it is a hazard by putting a little aluminum oxide or minor traces of copper sulfate in it, which would increase the flame. But I can tell you from first-hand experience it's not a problem with ethanol; you can see the fire.

Mr. **Glickman**. And my final question would be on the issue of corrosion. What do the visual indications indicate so far on the effects of the engine with regard to corrosion using alcohol versus using gasoline?

Mr. **Donahue**. Well, we have a set of test tanks with the various components of the fuel system suspended in it for a long period of time, and I can't tell you exactly for how long. To date, we have not found any corrosive problem. And if it should come about, we feel very strongly that that can be taken care of, either with adhesives or some new redesign of those portions of the fuel system.

Mr. **Glickman**. Any others? Any of you have any problems or comments on corrosion?

Dr. **Shauck**. As I have said before, I've got over 400 hours, and the end of the 200 hours the engine was torn completely down there and there was no corrosion in the engine itself. And we also tore it down at the end of 400 and saw no corrosion in the engine. Now, we have had a problem with the fuel tanks in the aircraft, aluminum tanks. We have a reaction between the alcohol and aluminum. We have solved that problem completely by sloshing the tanks with a standard aviation slosher compound.

Mr. **Glickman**. Finally, what recommendation do you have for Government in general, FAA, NASA, or Congress? Anything specific that we ought to be doing in this area?

Mr. **Donahue**. Mine, first of all, would be let's get a focal point, probably the DOE, and let's get the thing in hand and keep it moving along and not have private and public sources outside of the Federal Government who really has the leadership ability in that; do these things and present the forum that we have here this morning where we seem to be in here pushing for the particular alternative that we have been working on. We need to get somebody that's really going to normalize and focus on this. I think that Mr. Adkins made a great presentation on that and a great point.

Mr. **Glickman**. Anybody else have any thoughts on that?

Mr. **Paynter**. I feel that we could use high-altitude test laboratory when it's not being used; that would help an awful lot. We have been getting excellent—I meant to say this—we are getting excellent cooperation from FAA in our entire test program. They have assigned a project engineer to us, a man named Aguidel Arreva, who is doing a fine job, and we are delighted with FAA's attitude about it. I guess they can see the handwriting on the wall; they are going to be out of business if they don't start doing something to keep us in business.

Mr. **Glickman**. Thank you.

Mr. Carney?

Mr. **Carney**. Thank you, Mr. Chairman.

We have talked about pricing, the effects of ethanol and methanol on corrosion. What about the effects that these two fuels would have on the gaskets and seals in the engines?

Dr. **Shauck**. Well, all I can tell you is that in the last 1½ years we have had no seal problems whatsoever. Now, we did change some of the seals in the fuel injection system because there has been a good deal of experience in the people racing boats, and they knew they would have a problem with some of the diaphragms in the injector. We simply changed those with neoprene.

Well, we did have one other problem—the cork float in the fuel gauge in the tank. We have since put in a new one and coated it, and that's been the only problem we have had with the seals.

Mr. CARNEY. What about the lubricant problems?

Dr. SHAUCK. Well, we have had no excessive wear in the cylinders, and 425 hours is a considerable amount of flying time.

Mr. CARNEY. What about the valve guides?

Dr. SHAUCK. No problems.

Mr. CARNEY. Has everybody had that same experience on the panel?

Mr. PAYNTER. We have a lubrication additive that we have added lubricant, and we have not had problems at all anywhere in the engine.

Mr. PLATT. We have soak tested the major materials used in the Cessna 182 airframe, and the only problem we had anything negative was a plastic float which had swollen on us. At that time, I called a manufacturer of the carburetor and they sent us a stainless float. They assured me at that time if we had any trouble with any of the materials in the carburetor, they'd be happy to supply kits to any future purchasers or to ourselves, although through our soak testing we had nothing negative other than the float itself. And our experience has been that we found no incompatibility with our existing airframe.

With some previous methanol experience, there has been some corrosion, especially in your aluminum components. And from the standpoint of lubricity, I have had some conversations with a Dr. Blazer at Southern Illinois University who has used extensive research testing in diesels, and he has found that by adding about 3 percent, either corn oil or soybean oil, he eliminates any of this friction problem. And he has been using 200-proof ethanol as a diesel fuel and he has had no negative effects on his fuel injectors. In fact, he gets an increase.

Mr. CARNEY. By using corn oils, you lower your serum cholesterol, as well.

Performance: And I open this question to all three panelists—four, pardon me. The amount of fuel consumption that you have, using your fuels compared to aviation fuel, the amount of horsepower, that type of thing. Just in general, could you comment on that?

Mr. DONAHUE. As I said in my testimony, we are realizing approximately a 5-percent increase in horsepower on takeoff. In other words, we are getting a higher engine rpm. My flight—I have about 10 hours in the ethanol airplane—and my experience with flying the same 182, the same power train, on gasoline, I find no difference at all.

Mr. CARNEY. Gentlemen——

Mr. PAYNTER. We are getting—we are using a little more fuel—as I said, 1.3 times as much—at lower operating altitudes, and, strangely enough, above about 12,000 feet we have used less fuel than we did with gasoline. Our total range is about the same. We go a little bit faster because we are developing a little more power. And, as a result, we go a little further every hour. So we wouldn't feel that we had any reduced range. At my age, I don't want to stay up there. I run out of facilities before the airplane does.

Mr. CARNEY. Doctor?

Dr. SHAUCK. In the decathalon, we have a fuel flow indicator we have calibrated carefully, and we also have a data logger to make the university happy with the program. We calibrate everything very carefully and we do find we have a 20-percent decrease in range at standard operating altitudes for this aircraft, about 5,000, 6,000 feet. At 14,000 feet, we were getting approximately the same mileage, but that's only for a couple hours' worth of data.

The other data that we got at lower altitudes is very extensive data, and I feel comfortable with that. So I think we are going to take—until the engine goes or is modified extensively for alcohol, as I mentioned before, we are going to have a decrease in range, which is a problem.

Mr. DONAHUE. I didn't mean—Mr. Carney, I didn't mean to say that we—we also have experienced an increase in the use of about 15 percent. But I was just referring to the operating characteristics of the aircraft.

Mr. GLICKMAN. Will you yield to me for just a moment?

Mr. CARNEY. I yield to the chairman, please.

Mr. GLICKMAN. Is there any work being done in engines, specifically being designed for alcohol, so you won't have to do this modification or worry about the corn oil or anything else?

Mr. PAYNTER. Gordon Cooper has done a lot of that work, and he has some engines that are designed specifically for alcohol. I think Max put his finger on it. We are suffering a little bit of reduced range, if you will, coupled in our case with considerable improvement in performance because of power. But when you get into designing engines specifically for alcohol fuels, we are going to see some dramatic moves forward. Gordon has an engine that outperforms gasoline in every area.

Dr. SHAUCK. I'd like to mention, strictly to show you how the potential for alcohol in a piston engine—the last year in the very carefully controlled rally in Wisconsin, Don Kuna, in his modified Chevy station wagon, obtained 28 miles a gallon on 200-proof ethanol, and that car typically gets about 15 miles a gallon. The engine was modified extensively for use, for utilizing the alcohol. So if you can do it in that engine, you can do it in an aircraft engine.

Mr. CARNEY. In general, then, the three panelists agree that you will, one, cut back on your range; two, increase slightly on your power?

Mr. DONAHUE. In the present configuration of the engine, as Dr. Shauck said, when we get some new technology into the engines designed specifically for ethanol or methanol, we'll at least equal the parameters set out by gasoline.

Mr. CARNEY. The curve is on your side. You have just stated that, I recognize, and that you are all in agreement. Although each panelist spoke about different aspects of the performance, you are all in agreement with each other when comparing testimony. Would that be true?

Mr. DONAHUE. I certainly am.

Mr. PAYNTER. I am.

Dr. **Shauck**. Yes.

Mr. **Carney**. It certainly is very responsible, and I am looking forward very much to seeing firsthand the aircraft that you brought to Wichita, and I know it was a chore to do that on just your parts. And we appreciate that immensely.

And I would also like to point out that you do learn a lot of things in these hearings. In New York, if you robbed a bank, you would go to the slammer for 5 years; and in Illinois, you go to the still for 5 years, I guess.

Mr. **Donahue**. We denature it immediately.

Mr. **Glickman**. I want to thank all of you for testifying here today. It was most beneficial. And, again, we're looking forward to seeing the aircraft.

Mr. **Donahue**. Thank you, Mr. Glickman, and we thank the committee.

Mr. **Glickman**. Our next panel is the panel on safety-related issues. We have Mr. Murray Smith, Director, central region, Federal Aviation Administration; and we have Mr. Thomas J. Smith, chairman of the Energy Committee of GAMA, General Aviation Manufacturers Association.

I see out in the audience Ed Stimson, president of that organization. Glad to have you here, Ed.

It's a pleasure to have you both here, and why don't we go ahead, Mr. Smith, and let you give your statement, your testimony—well, Mr. Murray Smith. I'm looking again through the keyhole. I see two Smiths right there. And then we'll go with Mr. Thomas Smith. And, as I said before, you may feel free to summarize your statements because they'll appear in the record in their entirety. So why don't you begin.

STATEMENTS OF MURRAY SMITH, DIRECTOR, CENTRAL REGION, FEDERAL AVIATION ADMINISTRATION, ACCOMPANIED BY BARRY CLEMENTS, MANAGER OF AIRCRAFT CERTIFICATION DIVISION FOR THE SMALL AIRPLANE DIVISION IN KANSAS CITY, AND MARTIN LINDENAUER, REPRESENTING THE ENGINE CERTIFICATION DIRECTOR; AND THOMAS J. SMITH, CHAIRMAN, ENERGY COMMITTEE, GENERAL AVIATION MANUFACTURERS ASSOCIATION

Mr. **Murray Smith**. Thank you, Mr. Chairman. And we, too, appreciate the opportunity to be here. This is a very important hearing. We are interested in hearing everything we can about alternate fuels.

I have with me two gentlemen: Barry Clements, to my right—he is the Manager of Aircraft Certification Division for the Small Airplane Division in Kansas City; and Mr. Martin Lindenauer from Boston—he is representing the Engine Certification Director. So we are happy to be able to answer, I'm sure, your questions.

I have cut this down just a bit, though, and I would like to cover most of it because it pretty well draws together, I think, just what the role of the FAA is in this exercise.

First, I'd like to point out that the FAA fully supports the aviation community in its search for alternate fuels that can be used safely in small aircraft.

The Federal Aviation Act of 1958 as amended gives the FAA the responsibility for developing standards necessary to insure safe operation of our air commerce. The FAA is charged with the responsibility of assuring that adequate design standards are available and that no unsafe condition exists in the airplane or its engine. At this time, the regulations covering the use of fuels are considered adequate for the approval of alternate fuels and to assure safe operation under all operating conditions. As additional alternate fuels become available, new minimum requirements may be necessary. If it becomes necessary to develop new standards, we have the responsibility to determine that the airplane and engines used in service meet those standards.

It might be well to take a moment to review the FAA organization and certification process for engines and aircraft. There are four certification directorates within the FAA with the following assigned responsibilities: the New England region in Boston, engine and propeller; the central region in Kansas City, small airplanes—that is, airplanes less than 12,500 pounds; the southwest region, rotorcraft and helicraft; the northwest mountain region, transport airplanes.

Final responsibility for certification rests with the appropriate directorate, with each directorate having aircraft certification offices which deal directly with the public. For a new engine or aircraft design, the applicant applies to the local FAA aircraft certification office for type certificate, commonly called a TC. During the certification process, the FAA reviews the applicant's technical data and participates in the aircraft or engine testing which is required by the applicable Federal Aviation Regulations, or FAR's. If all the requirements are complied with, the aircraft or engine manufacturer is issued a type certificate.

The next step in the approval process is to assure that aircraft or engines produced conform to the type design, and this is accomplished by reviewing a manufacturer's quality control system. Upon satisfactory completion of the review, the manufacturer is issued a production certificate, or a PC. If an applicant other than the original holder of the type certificate wants to modify a product, either an engine or an aircraft which has already received a TC, he will be issued a supplemental type certificate, or STC after satisfactory demonstration to the FAA that the modification or modifications will not affect the airworthiness of the products.

The use of fuel, made to a specification which is different from the specification approved as part of the engine and airplane type design, requires FAA approval under the STC process. Two STC's are required for approval of alternate fuel, one for the engine and one for the airplane, because the engine and airplane have separate type certificates and both may be affected by the use of the alternate fuel.

Federal Aviation Regulation Part 33 provides the requirements for engine certification; and part 23, the requirements for small aircraft certification. In addition, there is an FAA advisory circular, AC20-24A, entitled "Qualification of Fuels, Lubricants, and Additives," which provide suggested procedures for approval of alternate fuels under the Federal Aviation Regulations.

Basically, FAR 23 for engines requires a 150-hour endurance test, a detonation test, and other tests which are deemed necessary to demonstrate that the engine will operate safely with the candidate fuel. The 150-hour test is one of accelerated severity, which includes longer periods of time at maximum power settings than normal engine operation. Accordingly, the advisory circular provides for the acceptance of 500 hours of normal flight as being equivalent to the 150-hour endurance test required by FAR 33.

In addition, there are tests required under FAR 23 for small airplanes to demonstrate safe operation of the aircraft fuel system. These include at least the following: one, engine cooling; two, comparative rate of climb; three, engine restart; four, hot weather operation; five, carburetor heat rise; and six, assurance that the engine produces rated power. Additional tests may be necessary, depending upon the fuel characteristics being examined. Also, compatibility of the fuel with the materials used in the engine and aircraft fuel system must be shown.

One of our ongoing projects in the area of alternate fuels began on July 14, 1983. Our Chicago Aircraft Certification Office, or ACO, met with representatives of the State of Illinois to review the feasibility of approving 190-proof ethyl alcohol, or ethanol, for use in the Cessna Model 182 airplane. This small airplane directorate, and the engine and propeller directorate, participated in this meeting. Preliminary evaluation of the project indicates that compliance with the applicable Federal Aviation Regulations will assure safe operation of the engine and airplane with this alternate fuel. The applicant has identified various modifications to the airplane and engine that will be necessary, but have not been fully developed at this time. Our Chicago ACO is working closely with the State of Illinois concerning approval procedures. A number of these have already been addressed here this morning.

In a few cases, FAA has granted experimental airworthiness certificates to an organization for a specific airplane involved in innovative alternative fuel work. Union Flights has been granted such a certificate for experimental work with straight methyl alcohol, or methanol, which is principally obtained by partial oxidation of natural gas, oil, coal or any combustible material. We have also granted an experimental certificate to Beech Aircraft so it can pursue its work with liquid methane. Some applications for supplemental type certificate approval of methanol have been received and are in a very preliminary stage. No such applications have been received for liquid methane because today's engines are optimized for operations with gasoline, modifications, or perhaps even complete engine redesigns will likely be necessary to permit efficient use of alternate fuels. The aircraft fuel supply and delivery systems may also have to be modified for satisfactory use of alternate fuels.

For any alternate fuel, a specification must be developed to control the fuel quality and the additives which may be necessary for safe operation.

In the case of the alcohols, for example, the percentage—or proof—of the alcohol in the fuel must be defined, as well as the permissible water content. In the case of ethanol, the type and amount of the denaturant to be added must also be specified. Both alcohols burn with an almost invisible flame, which compounds the seriousness of a fire in the event of an accident. Accordingly, a fuel additive would be required so that a visible flame is produced, thus making a fire more readily combatable. An additive to properly lubricate upper engine parts will probably be necessary for both alcohols, as well. The effect of these and other possible additives on the engine and aircraft parts, and on the operation of the aircraft, will have to be determined, as well as the effects of long-term fuel storage.

Various design problems are also anticipated when using ethanol, methanol or liquid methane as an alternative fuel. For instance, both ethanol and methanol, require the fuel to be heated, or else an alternate starting fuel must be used to achieve acceptable engine starting characteristics. Methanol is very corrosive of the materials commonly found in present-day general aviation fuel systems. Ethanol's low vapor pressure—or ability to produce vapors—compared to gasoline, may produce explosive mixtures in fuel tanks, thus requiring additional design considerations such as fire protection or altering the fuel to change the vapor pressure. The low heating value—or less heat energy per pound—of alcohol fuels compared with that of gasoline may also decrease aircraft range. Liquid methane presents other concerns. Because it is gaseous in its natural state, it must be pressurized and stored in special fuel containers. All of these problems must be resolved to assure proper and safe operation of aircraft using these fuels.

Assuming engineering ingenuity will resolve the problems I've mentioned, other issues must still be addressed. A specification must be developed for each alternate fuel to define the design and production limits of the fuel. Each engine and airplane must be tested to this fuel specification limit to assure that the engine will comply, and will continue to comply, with the FAR's, and is safe for operation.

Once that has occurred, the equivalent of a production certificate mentioned earlier must be evaluated to assure acceptable quality of the fuel being produced. A production and distribution system will have to be established which assures that alternate fuel being produced complies with all of the requirements of the fuel specification, and will continue to comply with those requirements.

In addition to the efforts of Union Flights in methanol, Beech in liquid methane, and the State of Illinois on use of ethyl alcohol in small aircraft, the FAA has also been involved in the evaluation of automotive gasoline, auto-gas, in small airplanes. The first supplemental type certificate for auto gas was granted to the Experimental Aircraft Association approximately 1 year ago. Since then, STC's have been expanded to cover the use of auto-gas in various small aircraft with particular engines.

In addition, the Mississippi Agricultural Aviation Association is conducting a service evaluation of auto-gas, which is being monitored by the Central Region Directorate. The service evaluation is for a 1-year period for agricultural aircraft operating in Mississippi. And I might add at this point that they are restricted to agricultural aircraft.

We recognize that auto-gas is not considered an alternate fuel in the context of energy independence; however, these approvals have set the stage for identifying problems that must be resolved for the safety approval of other fuels.

In an effort to gain better understanding of how auto-gas is distributed and tested to conform to appropriate specifications, the FAA held a public meeting on April 5, 1983. The meeting was very well attended and informative on the use of auto-gas in small airplanes. The minutes of this public meeting are available if you would like a copy for the record. The main points which were made at the meeting were as follows: One, technical evaluation of the auto-gas approvals made to date were adequate within the specific confines of the particular engine, aircraft and fuel parameters; however, significant concern as to the general suitability of auto-gas in light aircraft was expressed by industry representatives. All future approvals should be granted on test data with each engine/airplane combination. There was no method presented that would allow simplifying future approvals where there are significant differences from models already approved.

The second point: The distribution system of auto-gas differs substantially from that of aviation gas. It was determined that the pilot/owner cannot readily assure that the auto-gas he buys meets American Society for Testing and Materials [ASTM] Specification D-439. A system will have to be developed to enable the pilot/owner to determine that the auto-gas he purchases meets specification D-439 and is free of contaminated materials.

The third point: The current ASTM specification D-439 is for automotive fuels used in ground vehicles, and the ASTM committee for D-439 only considers the automotive environment. To assure that any changes to D-439 will not adversely affect the use of this fuel in an aircraft, it would be necessary to specify the ASTM specification by revision date in the type design data.

Fourth point: As the fuel system becomes more complex—that is, different materials, fuel pumps, low wing aircraft, et cetera—sensitivity to vapor lock and material incompatibility to additives increases. Accordingly, each airplane engine and aircraft must be tested using the alternate fuel to insure compliance with applicable regulations. Results of tests must be carefully evaluated to assure continued safe operation of the airplane.

As you can see, Mr. Chairman, the FAA Directorates responsible for general aviation aircraft and engines are committed to a cooperative effort with industry to find alternate fuels for general aviation aircraft. Our experience today indicates that the FAA's current regulations and testing procedures are adequate to process applications for STC's for alternate fuels in a timely manner. They are also adequate to meet our ultimate goal, assuring that any STC which is approved for the use of alternate fuels will not compromise aviation safety.

As work in this area increases, we will make any necessary modifications to our rules and procedures to assure that we can continue to meet these goals.

And that concludes my prepared statement, Mr. Chairman.

[The statement of Murray Smith follows:]

Testimony of Murray Smith, Director, Central Region, Federal Aviation Administration, before the House Committee on Science and Technology, Subcommittee on Transportation, Aviation and Materials, concerning alternate fuels for general aviation aircraft. Wichita, Kansas. August 29, 1983.

Mr. Chairman and members of the Subcommittee:

I appreciate the opportunity to present the views of the Federal Aviation Administration (FAA) on the use of alternate fuels in small airplanes. The oil shortage of 1974 made clear the need for fuel from sources other than petroleum. Moreover, despite the general surplus of oil in the world, there are increasing spot shortages of grade 80 aviation gasoline. It is prudent, therefore, that alternate sources of fuel be developed to supplement, and perhaps someday replace, petroleum-derived fuels. The FAA fully supports the aviation community in its search for alternate fuels that can be used safely in small aircraft.

The Federal Aviation Act of 1958, as amended, gives the FAA the responsibility for developing standards necessary to assure safe operation of our air commerce. The FAA is charged with the responsibility of assuring that adequate design standards are available and that no unsafe condition exists in the airplane or its engine. At this time, the regulations covering the use of fuels are considered adequate for the approval of alternate fuels and to assure safe operation under all operating conditions. As additional alternate fuels become available, new minimum requirements may be necessary. If it becomes necessary to develop new standards, we have the responsibility to determine that the airplane and engines used in service meet those standards.

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c) Engine Restart
d) Hot Weather Operation
e) Carburetor Heat Rise, and,
f) Assurance that the Engine Produces Rated Power.

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1. Technical evaluation of the autogas approvals made to date were adequate within the specific confines of the particular engine, aircraft and fuel parameters. However, significant concern as to the general suitability of autogas in light aircraft was expressed by industry representatives. All future approvals should be granted based on test data with each engine/airplane combination. There was no method presented that would allow simplifying future approvals where there are significant differences from models already approved.

2. The distribution system of autogas differs substantially from that of aviation gas. It was determined that the pilot/ owner cannot readily assure that the autogas he buys meets American Society for Testing and Materials (ASTM) Specification D-439. A system will have to be developed to enable the pilot/owner to determine that the autogas he purchases meets Specification D-439 and is free of contaminated materials.

3. The current ASTM Specification D-439 is for automotive fuels used in ground vehicles, and the ASTM Committee for D-439 only considers the automobile environment. To assure that any changes to D-439 will not adversely affect the use of this fuel in an aircraft, it would be necessary to specify the ASTM specification by revision date in the type design data.

4. As the fuel system becomes more complex (i.e., different materials, fuel pumps, low-wing aircraft, etc.) the sensitivity to vapor lock and material incompatibilitly to additives increases. Accordingly, each airplane engine and aircraft must be tested using the alternate fuel to ensure compliance with applicable regulations. Results of tests must be carefully evaluated to assure continued safe operation of the airplane.

As you can see Mr. Chairman, the FAA Directorates responsible for general aviation aircraft and engines are committed to a cooperative effort with industry to find alternate fuels for general aviation aircraft. Our experience to date indicates that the FAA's current regulations and testing procedures are adequate to process applications for STC's for alternate fuels in a timely manner. They are also adequate to meet our ultimate goal, assuring that any STC which is approved for the use of alternate fuels will not compromise aviation safety. As work in this area increases, we will make any necessary modifications to our rules and procedures to assure that we can continue to meet these goals.

That concludes my prepared statement, Mr. Chairman. At this time, I would be happy to respond to your questions.

Mr. GLICKMAN. I appreciate your testimony. Mr. Thomas Smith, it's a pleasure to have you here.

Mr. THOMAS SMITH. Mr. Chairman, I'm pleased to be given this opportunity to testify on behalf of GAMA, General Aviation Manufacturers Association which, as you know, represents 34 companies that manufacture airframes, engines, avionics, and supporting equipment for general aviation.

We, of course, are also appreciative of your interests for alternate fuels for aviation and our industry. For many years our association has been supportive of alternate fuels and multifuel engine development. As we look ahead to the future, we see eventually the exhaustion of the petroleum-based products, as we know them today. And it's in our best interests, of course, as an industry to make preparation for that eventuality.

Since 1979, as a matter of fact, we have urged that NASA, and have supported development through NASA of a multifuel engine that is designed to fit into today's presently sized small aircraft and would be capable of burning a variety of fuels.

In looking at the known spectrum of fuels that we have today, we conclude that for general aviation gasoline, liquid propane and aviation kerosene are probably the best practical alternatives when you consider the tankage that is needed and the given amount of energy liberated from that material.

Given what we know today, jet fuel seems to be the best across-the-board fuel for general aviation. It's available, it's fairly simple to produce, and because of its volume production for the airplanes, it will probably be around for a very long time, though it may be a shift from crude oil to shale oil.

The conclusion, therefore, that we have reached in GAMA is a forecasted need for a new type engine compatible with jet fuel for use in small general aviation aircraft in the future. And for research and development to develop such, we have looked for leadership from NASA.

If we focus our attention on existing fuels, the two fuels in aviation used today as we have come to know them are aviation gasoline and jet fuel. Aviation gasoline as described in ASTM D-910, jet fuel described in D-1655, no other fuels are approved or endorsed for use in our aircraft by the airframe or the engine manufacturers.

We in GAMA, of course, are cognizant of the efforts underway with a variety of STC actions on auto-gas, along with some of the work being done in alcohol fuels, and of course some of the innovative work being done by Beech Aircraft, the U.S. Army and others with liquefied gaseous products.

In addition, and perhaps more importantly for the very long term, we continue to closely monitor the work being done by electric propulsion technology which utilizes lithium hydroxide as the energy source, even though this today is in the classified area in many cases.

We manufacturers fully realize the value of exploring alternative fuels and multifuel engines. Some day one or the other will be critical to our industry's very survival. We also fully realize and would hope that you do also, that unless our aircraft maintain an exemplary safety record so that the flying public retains a degree of confidence in their own safety in general aviation airplanes, the result could be virtually extinction of general aviation.

This concern for private safety was the philosophy of the Wright Brothers who built a wind tunnel and tested models of airfoils and control systems long before and even after their first successful flight. This philosophy was part of the work that became the D-910, the spec for aviation gasoline.

The manufacturers of engines and airframes have, over the years, tested and certified their gasoline-powered products with fuel meeting that spec, D-910. We have millions of hours and have accumulated time on various engines and airframes, and know almost all there is to learn about the effects of these fuels, their reactions on the elastomers, the fuel tanks, and on the engines themselves. We don't presume to know all there is, of course, about these fuels.

In comparison, we don't know very much about the effects of auto gas or alcohol-gasoline mixtures on our engines and aircraft. This is not the same as saying that the use of such fuels is unsafe. Without knowing a lot more than we know today, we cannot say the usage is safe.

Perhaps we are being too cautious, but in the very, very real world of products liability that we all see today, we cannot afford to be less than cautious. Even with a strictly controlled spec and strict quality control of the product, and even with the testing of both engine and aircraft in accordance with the FAA regulations, problems have crept in, and empirical solutions to these problems have been required. In the flying business, of course, you can't pull over to the side of the road and wait for a tow truck.

Present automobile gasoline approvals by FAA or other foreign certifying authorities for airplanes and engines specifications, these approvals apply only to the specific airplane and engine combination, using a specific quality of fuels meeting ASTM D-439 at a regulated cleanliness level, handled in a specific manner and used within a specific flight envelope.

We are concerned that the use of auto gasoline in aircraft will produce a number of problems adverse to safety that are not evident in the granting of an STC for the use of auto gas in a specific aircraft. For example, some persons will utilize auto gas in airplanes for which STC's have not been issued, believing that the use of auto fuel is broadly approved for use in all aircraft, and the safety hazard that may be induced if the auto gas does not meet ASTM Spec D-349, which in many cases is the case, though the ASTM has responsibility to pilots in this country to assure that the auto gas meets D-439, how is the pilot to know the fuel, in fact, meets this specification.

Further, and perhaps the greatest safety issue, is the problem of getting the auto gas to the airplane, particularly the transportation and cleanliness of the containers used to transport the fuel from the local filling station to the airplane itself. It is most likely this fuel will be transported in cans from the gas station by automobile to the plane site.

Aside from the highway hazards this transportation creates, filling a high, or for that matter, a low wing airplane from fuel cans is most hazardous to the person, the airplane being fueled, and the airplanes in the vicinity.

Fueling through the correct system of fuel pump and nozzle from underground tanks or structures has been and is a safely demonstrated process.

In summary, GAMA has continued to support and encourage NASA research and development to develop the technology for small general aviation aircraft engines capable of utilizing multiple fuels. As for the use of auto gas and alcohol-based fuels in general aviation for the near term, we advise caution. Too much is unknown and there needs to be more effort spent to get the needed answers.

I appreciate this opportunity to speak, Mr. Chairman.

Mr. GLICKMAN. Thank you very much both for your testimony. Mr. Thomas Smith, do you know if there is any research being done now with respect to developing an engine which is compatible with jet fuel? The gentleman, Mr. Donahue from the State of Illinois, testified that there was some work going on in mixing alcohol with jet fuel, but on the question of developing an engine which is compatible, is anybody doing any work on that?

Mr. THOMAS SMITH. There are several efforts underway that I'm aware of, Mr. Chairman. One which is Curtiss-Wright, who is developing a rotary engine, the Wankle (sp) engine; has been working on that for a number of years and continues to work on it today. The nature of that engine is such that it could burn a variety of fuels.

The other efforts underway by one or both of today's engine manufacturers, to look at what is known as a stratified charge engine, which is really a combination of the diesel and a piston, sparkplug-type engine, which would have the good features of both fuels, and also be capable of burning a variety of fuels.

Mr. GLICKMAN. You know, this points up this subject which has been going on through the Department of Energy, automobile areas, and one of the things that I am personally concerned with is their reluctance to actively pursue the level I would like to see the research and ceramics and gas turbines, Stirling engines, engines which are capable of multifuel burning, and I think that's the kind of thing you are talking about, which would have a great adaptation to the airplane market, and things which may be less inclined, that the private sector would have the funds and capability of doing research.

Mr. THOMAS SMITH. First, I believe that we are concentrating on developing an engine that can burn a variety of fuels.

Mr. GLICKMAN. I guess the engines, if we are cut off, sooner rather than later we would not have an engine for at least 10 years, and the cut may make it easier or more feasible for us to go to the first route. In light of that, I'd like to ask you. Your statement indicates an understandable reluctance to accept alternative fuel use because of potential liability problems, potential safety problems, unknown safety problems that could result. In some respects your statement echos the testimony we got from Chrysler, GM, and Ford when we had earnings like this on automotive fuels several years ago.

There is a difference, I realize, in terms of safety implications, though, on the airplane flying above the ground, but there was a lot of parallels, you know, unknowns, and there were a lot of indications of the same problems, that most did not materialize. A few did, but most did not. I just ask you, do you have a plan or recommendation of your own in case we have another fuel crisis in the next 4 or 5 years and you are going to get shut out again like you did in 1973?

Mr. THOMAS SMITH. Well, the tradeoff there is, do we want to accept liability for an unproven, potential unsafe product? There is little that we can do to forestall a disruption in the Middle East. A fuel crisis, there will be another fuel crisis, whether it's in 5 years or 10 years or 20 years, there will be another fuel crisis, we believe. We, along with other forms of transportation, probably are the most—one of the most efficient forms of transportation. So if there is any available fuel at all, theoretically the users of the most efficient products will tend to get their fair share.

Back to this tradeoff issue, however, I don't think it would be in our best interests to sacrifice what we manufacturers of products today, not just aviation products or automobiles, but all manufactured products today that are used by the public are coming under greater and greater pressure relative to the liability for the proper use of that product, and given the thinking of today's courts and today's juries and the tremendously large settlements that are being made, we cannot and will not take the position that we are willing to sacrifice our company's reputation and our product's reputation to perhaps make an expeditious decision on an unproven product.

Mr. GLICKMAN. Well, I also realize that because of the economic state of it, companies in your industry, not all but some, there is not a great desire to move ahead with large amounts of research dollars because the moneys aren't available. I guess my concern, and my comment to the manufacturer, is to not exclude the idea of fuels as a part of your research efforts.

We have seen one of the companies here talk about it, and I guess the implication in your statement is that you are very reticent on moving ahead with fuels because of a great amount of unknowns. My fear is that the engine work, if it comes, will be very slow. After all, the auto companies have more incentive than the aircraft companies, to do a great deal of engine work, and haven't done it because the status quo is always more acceptable than, you know, moving ahead with major new engine changes, and many do not work. In fact, most do not work.

My fear is that—that if the private sector doesn't show some interest, real interest in the alternative part of the picture, we are not going to get anywhere when the next fuel crisis hits us, and I just encourage you to take an active role in shaping the fuels side of the picture so you come up with fuels that you feel more comfortable with rather than maybe leaving the work to the experimental folks, which I'm sure is, you know, I would assume that you would not feel comfortable with taking the tests that are done by the Experimental Aircraft Association and moving in right away.

I think the FAA probably wouldn't let you do it anyway, but I would again make my point, that I think that the inclination to look at the engine side is fine, but my guess is that that will require significant capital expenditures, and given the current budget problems we have, I doubt it's going to come from the Federal Government. Rather dramatically they are cutting back on all the automotive stuff, so, and probably doesn't even have the priority that that does.

So I thought I would make my point to you on that. I'm not trying to be argumentative. I think you raised some interesting questions and I think it was worth the response. Mr. Carney?

Mr. CARNEY. Thank you, Mr. Chairman. And Mr. Thomas Smith, you represent the majority, if not all, of the larger aircraft manufacturers—small aircraft manufacturers.

Mr. THOMAS SMITH. All general aviation, sir, in the United States.

Mr. CARNEY. I know it's very difficult for you to speak for them all in one voice, but I would suspect that competition in America, being what it is, there might be some small, even perhaps small in size an small aircraft manufacturers, what I'm trying to say, who might be looking at alternate engines that would utilize these fuels to get the competitive edge. Would you know of any cases of that nature?

Mr. THOMAS SMITH. I don't know of any specifically, but I'm sure that there are a variety of things underway with some liquid-cooled engines that used to be used in aviation back before World War II and during World War II, that have some possibility. There are some people working in California on a liquid-cooled aircraft engine. The problem with developing enginess, other than taking one that's off the shelf, made for another use, is the tremendous investment in tooling and equipment and so forth just to get into the engine business. A tremendous—millions of dollars to do that.

The two engine manufacturers in the United States today, Continental and Lycoming, make virtually all of today's piston engines.

We have, as I mentioned, Curtiss-Wright that is developing on an R & D basis a rotary-type engine, but I think the likelihood of a small airframe manufacturer looking other than to those three or four sources, perhaps to an engine that is not presently certified for our aircraft use, I think would be—it's possible, but I don't know of any in the certified-type products, other than in the recreational ultralight-type vehicle.

Mr. CARNEY. One of the major reasons we are here in Wichita is the fact that I guess you could call it the capital of small aircraft manufacturing in the United States, that they have had problems with sales since 1973. Don't you believe that's associated with the fact that it's become so expensive for fuels?

Mr. THOMAS SMITH. I don't think fuels have anything to do with the decline of aviation sales. I think that the industry is suspect and is controlled by what we call capital investment in this country, and most of today's airplanes are capital investments for the people that buy them, much the same as a milling machine is for an industry or for a business.

We saw the growth of aviation rise and fall based on the economy of the country. The industry, not only the aviation industry, but all capital goods went through a tremendous recession in 1959, lasted until about 1961, grew at a 7- to 10-percent annual rate to 1969. The 1969 economic crisis in this country, with not only the aviation industry and general aviation, large companies like Boeing laid off two-thirds of their employees, the machine tool industry.

All the capital type goods which are directly proportional to the level of the economy surged in 1969 to 1971 recession. Following that recession, the economy grew again at a 7 to 10 percent annual rate, so did aviation, until the last recession of—depends on how you define it, 2 years ago perhaps, which appears to be bottomed out and slowly heading upward now. And I would forecast that same growth to reappear in capital goods and aviation in the balance of the eighties.

I don't think that fuel has more than a 10 percent factor in the rise and fall of general aviation sales.

Mr. CARNEY. During the 1973 fuel crisis, wasn't it true that the GA industry was singled out as one that was perhaps not that important to our Nation and they got the—if you want to say, the sticky end of the lollipop when it came to how much fuel would be available for them, wouldn't that have an adverse impact on selling small planes?

Mr. THOMAS SMITH. You mean political realities of an industry that was not important in the country?

Mr. CARNEY. The business realities of selling something that there is no fuels to fly.

Mr. GLICKMAN. If I may, the lack of a stable fuel supply at a reasonable price, would't that have something to do with your ability to sell airplanes?

Mr. THOMAS SMITH. Sure.

Mr. CARNEY. Not having the fuels to fly it?

Mr. THOMAS SMITH. Sure.

Mr. CARNEY. So there has to be some concern about the availability of aviation fuel to those who build the planes.

Mr. THOMAS SMITH. There is a concern. But back to your original statement of the fall of aviation in 1973. I don't think that the decline in aircraft sales over the last 20 or 30 years has been nearly tied into the fuel availability as it has been to the general economy.

Mr. CARNEY. Well, even the 10 percent factor which I, although not being an expert, I would somewhat disagree, I think it's probably higher. People must have some apprehension about making a capital investment in something they might not have the capability to fly because they have a lack to utilize as much as they would like, because they have a lack of fuel available, or because of the increase in costs.

We had one witness say that his—one of his largest customers just stopped using aircraft because of the cost of operating the aircraft, so that has to have an impact on aircraft sales, I would think.

But, anyhow, I didn't want to get off on that tangent, quite honestly. What I was trying to bring out, and obviously we have some disagreements, I would think that the general aviation industry for competitive reasons would be pursuing alternatives, and what I got from your testimony, and I can fully appreciate this, is that the atmosphere today in industry product liability is such that you have to be extremely careful no matter what you do.

With each and every move that you make you have to be extremely careful, and that perhaps has a greater impact on your industry than the fuels problem. And I can appreciate that, but I find it hard to believe that you put such little emphasis on the fuels. Of course, that's why we are here, to listen to you and to learn.

Mr. THOMAS SMITH. Well, my emphasis on fuels I think applies more to the past than as I, in my testimony, alluded to, that eventually fuel will become a problem. It's not a problem today. Eventually it will become a problem for petroleum-burning vehicles, not just aircraft, all petroleum-burning vehicles.

Mr. CARNEY. Fuel is not a problem today because we have some stability in the world, but fuel could be a problem by 6 o'clock tonight.

Mr. THOMAS SMITH. I don't think so.

Mr. CARNEY. You have more confidence than I do.

Mr. Murray Smith, your testimony was very complete and I had some questions and you answered them all in your testimony. And Thomas Smith, I appreciate your testimony, and certainly I've been enlightened by some of the things you have said. Thank you very much.

[The prepared statement of Mr. Thomas Smith follows:]

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STATEMENT OF
THOMAS J. SMITH, CHAIRMAN, ENERGY COMMITTEE
GENERAL AVIATION MANUFACTURERS ASSOCIATION
ON
"ALTERNATIVE FUELS FOR GENERAL AVIATION"
BEFORE
SUBCOMMITTEE OF TRANSPORTATION, AVIATION AND MATERIALS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
AUGUST 29, 1983

We appreciate your interest in alternate fuels for use in general aviation. Our Association represents 34 companies that manufacture general aviation aircraft, engines, avionics, component parts and training aids.

Our Association has, for many years, been most supportive of the development of alternate fuels and propulsion systems for use in the general aviation aircraft of the future -- the aircraft that will replace the predominant gasoline burning, piston engine powered airplane being manufactured today. Since 1979, we have urged NASA to proceed with a multi-faceted R&D program to develop the prerequisite technologies needed to produce alternative powerplants for use in the 1990's and beyond. The main reason for our request is the need to have engines that can use a wider range of fuels than today's piston engine. It matters not whether these future engines are rotary, diesel, or ceramic gas turbines. They could use either existing fuel stocks or possibly even synfuels.

These engines will be forced to use whatever fuel is available. What we need, therefore, for the lighter end of the general aviation market, is a fuel that is readily available, relatively inexpensive, easily and safely handled and consistent in quality by being controlled by a technical specification or standard. It should also have a high BTU content per gallon or pound.

In looking at the known spectrum of fuels, we have concluded that, for general aviation, gasoline, as we know it today, liquid propane, and aviation kerosene are the best practical fuels when you consider the tankage needed to contain a given amount of energy in the form of BTU's. For heat liberating engines, aircraft range is proportional to the heating value of the fuel. More BTU's per unit of fuel mean greater range.

Given what we know today, jet fuel seems to be the best across-the-board fuel for general aviation. It's readily available, simple to produce and, because of its volume production for the airlines, will probably be around for a very long time -- though its base may shift from crude oil to oil shale or coal.

Therefore, we project the need for a new type engine -- compatible with jet fuel -- for use in the general aviation aircraft of the future. For the R&T to develop such engines, we look to NASA.

If we focus our attention on existing fuels, the two in aviation use today are aviation gasoline and jet fuel. Aviation gasoline is described in ASTM Specification D-910. Jet fuel is described in ASTM Specification D-1655. No other fuels are approved or endorsed for use in our aircraft by the airframe or engine manufacturers. We -- GAMA -- are, of course, cognizant of the efforts underway with a variety of STC actions on autogas, along with some of the work being done with alcohol fuels, and, of course, some of the innovative work being done by Beech Aircraft and the U.S. Army with liquified gaseous fuels. In addition, we continue to closely monitor the work being done in electric propulsion technology using lithium hydroxide as the energy source.

We manufacturers realize the value of exploring alternative fuels and multi-fuel engines. Someday, one or the other will be critical to our industries very survival. We also fully realize, and would hope you do also, that unless our aircraft maintain an exemplary safety record, or if the flying public loses confidence in their own safety in general aviation airplanes, then the result would be the virtual extinction of general aviation.

The manufacturers of engines and airframes have, over the years, tested and certified their gasoline-powered products with fuel meeting ASTM Specification 910. We have millions of hours of accumulated time on various engines and airframes and know almost all there is to learn about the effects, actions, and reactions of these 910 fuels on the engine, the elastomers and the other materials in the fuel systems. I do not presume to say that we know all there is to know.

In comparison, we don't know very much about the affects of auto fuel and alcohol/gasoline mixtures in these engines. This is not the same as saying that use of such fuels is unsafe. But without knowing a lot more than we know now, we cannot say such usage is safe. We are, perhaps, in the minds of some, being too cautious but, in the very real product liability world of today, we cannot afford to be less than cautious. Even with a strictly controlled specification and strict quality control of the product, and even with the testing of both engine and aircraft in accordance with FAA regulations, problems have crept in and empirical solutions to these problems were required.

Present auto gas approvals by FAA or other foreign certifying authorities are airplane and engine specific. The approval applies only to the specific airplane and engine combination, using a specific quality of fuel meeting ASTM D-439, at a recognized cleanliness level, handled in a specific manner, and used within a specific flight envelope.

We are concerned that the use of auto gasoline in aircraft will introduce a number of problems, adverse to safety, that are not evident in the granting of an STC for use of autogas in a specific aircraft. For example:

Some persons may utilize auto gasoline in airplanes for which STC's have not been issued, believing that the use of automotive fuel is broadly approved for use in aircraft. Safety hazards may be induced if the auto gasoline used does not meet ASTM Specification D-439. Though an STC places the responsibility on the pilot-in-command to assure that the auto gasoline meets D-439, how is the pilot to know that the fuel, in fact, does meet this specification?

Further, and perhaps the greatest safety issue is getting the fuel from a local filling station to the airplane. It is most likely that this fuel would be transported in cans, via automobile, to the plane site. Aside from the highway hazard this transportation creates, filling a high-wing airplane from fuel cans poses hazards to the person, the airplane being fueled, and airplanes in the vicinity. Fueling through the current system of fuel pump and nozzle from underground tanks or trucks is a safely demonstrated procedure.

In summary, GAMA has continued to support and encourage NASA R&T to develop the technology for small general aviation aircraft engines capable of utilizing multiple fuels. As to the use of auto fuel and alcohol based fuels in general aviation, for the near term we advise caution. Too much is unknown and too little effort is being expended to get all the needed answers.

Thank you for the invitation to testify. We would be pleased to answer any questions that the Subcommittee might have.

Mr. CARNEY. I think the chairman went away, so I'd like to go ahead. This is the first time I was ever chairman. I like this. I'll go ahead and introduce the next panel, if I may.

We have Dr. William J. Wells, III, assistant manager of new product development for Celanese Chemical Co. from Dallas, Tex., and Mr. J. Robert Wade, president of Kentucky Agricultural Energy Corp. of Franklin, Ky.

Gentlemen, as you know, we have asked that you summarize your testimony. Your testimony will be submitted for the record in its entirety. If you could summarize we would appreciate it.

STATEMENTS OF DR. WILLIAM J. WELLS III, ASSISTANT MANAGER, NEW PRODUCT DEVELOPMENT, CELANESE CHEMICAL CO., DALLAS, TEX.; AND J. ROBERT WADE, PRESIDENT, KENTUCKY AGRICULTURAL ENERGY CORP., FRANKLIN, KY.

Dr. WELLS. Good morning, ladies and gentlemen. I'm Bill Wells of Celanese Chemical Co., in Dallas, Tex., and I would like to take this opportunity to thank Representative Glickman and his fellow committee members for the opportunity to speak this morning on our perspective on alternate fuels for general aviation. Actually my remarks will be somewhat broader in scope, addressing not only aviation but also America's other energy requirements, both for transportation and power.

Celanese Corp., strongly believes that home-produced alcohols such as methanol and ethanol are truly viable fuels for a not too distant future, giving us clean air and energy independence. At the same time, since Celanese Corp., is the world's largest producer of methanol, I shall confine my remarks to that chemical today.

First, a little background on methanol. It is the simplest member of the alcohol family. Each molecule contains one atom each of carbon and oxygen and four atoms of hydrogen. Discovered in the late 1600's it was produced commercially from the destructive distillation of wood from the mid 1800's to about 1923, thus its common older name, wood alcohol. From the twenties on, its main method of production has been the catalytic reaction of synthesis gas, or syn-gas as it is usually called, a mixture of hydrogen and oxides of carbon.

It is particularly relevant that syn-gas was originally made from coal, later from petroleum, and more recently from natural gas. Our enormous reserves of coal hold the key to our long-term energy requirements in the form of clean burning methanol. For methanol, depending on the relative cost and availability of feedstock choices, can be made from any carbon source, biomass, coal, lignite, peat, even garbage, and still it will be the same final chemical with the same predictable combustion characteristics, 5 percent or less, of North American methanol demand. It is a mainstay in the chemical industry, going into a variety of applications, in housing, automotive, aircraft, and consumer goods such as resins, coatings, inks, adhesives, phamaceuticals, herbicides, pesticides, and so on. But there is a growing consensus that the big future market for methanol will be fuel.

One of the first considerations that comes to mind for a fuel is supply. Where will it come from and will there be enough. For methanol, natural gas will remain the chief raw material source for perhaps the next two decades or longer, depending on the rate of growth of methanol as a fuel. It is the location and source of this gas that will likely change.

Natural gas has long been a nuisance in many petroleum producing countries, representing 10 to 20 percent of the energy coproduced in a well, along with crude oil, and usually it is flared to get rid of it. Our energy-hungry world can ill afford such waste and there is movement underway, especially in developing nations, to turn this wasted resource into much needed cash in the form of ammonia and methanol.

Production of the latter is being hampered by a current lack of fuel market; hence, the chicken and egg syndrome that is widely discussed, which comes first, the fuel or the vehicle it will power. It is difficult for either side to move first without assistance. Regardless, as the market develops and petroleum becomes scarcer and more expensive as it must, coal will move to the forefront and become the predominant methanol raw material, perhaps for centuries to come. Thus, it has been labeled by Ford Motor Co. and others as the fuel of the future.

This brings us to another important consideration: Will the fuel perform? The answer is an unqualified yes. The annual Memorial Day race at the famous Indianapolis Brickyard, where methanol is the only fuel allowed, is proof of the high performance nature of this fuel. Its characteristics are well-known and only economics have kept it from being the fuel of choice.

In 1926, methanol sold for an average of 40 cents per gallon. In 1982, due to improved technology and worldwide oversupply, the Gulf Coast price for methanol was only a few cents a gallon higher. Thus, in spite of its BTU per gallon disadvantage, methanol is today an economical aviation fuel, for example, both for piston and turbine aircraft.

As for the energy density differential, which is widely discussed, there is growing hard evidence that the thermal efficiency—that is, the efficient use of available energy in a given gallon of fuel—is much better for methanol relative to conventional hydrocarbon fuels. This appears to be true for a wide variety of methanol end uses, from light-duty to heavy-duty vehicles, from aircraft to stationary power generators.

Methanol is being looked at as an efficient fuel in all of these applications because you must consider each fraction of the barrel when you are considering substituting for a substantial portion of our crude oil purchases. This is, we believe, strategically important for America to find a simple, economical, reproducible, easy to produce, thermally efficient and clean burning fuel, which substitutes directly in every application for the crude oil based fuels it replaces.

This brings us then to the final and perhaps most important consideration for any alternate fuel—the environment. And this is where alcohol fuels really shine. The same lean burning characteristics of methanol that make it thermally efficient also make it clean. Documentation by the EPA, the Jet Propulsion Laboratory and numerous others have shown dramatically reduced oxides of nitrogen, hydrocarbons, and carbon monoxide, both from piston and turbine combustion engines. Since sulfur must be removed prior to methanol synthesis, sulfer oxides, a leading suspect in the acid rain controversy, are absent in the emissions.

As an added benefit, particulates from a compression ignited diesel-type engine are almost nonexistent, while at the same time stringent nitrogen oxide requirements are met. This fact was vividly brought home to me last week at the Golden Gate Transit Authority's bus yard in Marin County, Calif. There I rode on the world's first 100 percent methanol-powered two-cycle diesel coach. This bus was developed by an American company, the Detroit Diesel Allison Division of General Motors, and that prototype is expected to be in full revenue service within a month. The ride was remarkable. There were no particulates observed at any time and the exhaust was not unpleasant in the least.

This remarkable breakthrough is being matched in sparkignited engines by the Ford Motor Co., where a peppy clean-burning fleet of 600 four-cylinder Escorts has just been sold for Government and private fleet operations. We have purchased four ourselves with the intention of documenting their efficiency, performance, and emissions characteristics, and have already found them to be a substantial improvement over their gasoline counterparts from a driver performance point of view.

In the aircraft area, you have heard testimony today of improved performance and efficiency, and I know more work is planned. Programs are also underway in the following methanol-related areas: tractor and off-road heavy duty diesel, locomotives, turbines for power and aircraft, over-firing for NOX reduction in utility boilers, octane enhancement in conventional hydrocarbon fuels and catalytic dissociation for even higher thermal efficiencies and improved emissions.

In summary, I would like to leave this committee with the following thoughts: An oversupply of nearly 1 billion gallons of methanol annually exists in North America today, and it will continue to be there for the next 4 or 5 years, depending on how fast the fuel market develops. Conventional chemical uses will affect it little. This gives us a window to develop significant new industries here at home, based on a readily available, clean burning fuel, with a strong future for domestic production from our most valuable long-term resource, coal.

We can develop the infrastructure for this clean coal fuel of the future today by initiating and carrying out full-scale demonstration programs over the next few years using our current overcapacity, confident in the knowledge that remote and even domestic shut-in supplies of natural gas are available at economically attractive levels to bring us to that future time when crude prices make our coal attractive. That time might not be so far off, for Eastman Chemical is bringing up a coal-to-methanol plant this year in Tennessee. What looks to be a return to the past is, in fact, a major step into the future.

Again, thank you so much for your time and attention.

Mr. GLICKMAN. Thank you, Dr. Wells. I'm sorry that I was not here for the beginning of your testimony, but we appreciate your being here.

Mr. Wade, why don't you go ahead and proceed.

Mr. WADE. Thank you, Mr. Chairman, and members of the head table, and ladies and gentlemen. I bring greetings from the Garden Spot of the World, Franklyn, Ky., and I will approach the situation in a little bit different attitude, I expect, than the other people who have been on the panel.

My background is farm and elevator operation and, you know, I'm very aware, and I'm sure that the people in the Congress are very aware, of the many surpluses that we have in farm commodities. I think I got started in this business in 1974. I was going to an American Farm Bureau Board meeting and I nearly missed my airplane because I got in a fuel line trying to get enough fuel to get the rest of the way to the airport, because I hadn't watched my fuel gauge too close. And I got to thinking there had to be some way that we could supply some fuel and not be caught in this trap again.

I'm sure you all are very aware of the PIK program that's now in effect, the many programs that have been in effect to handle farm surpluses for the many years in the past, and there are probably more in the future.

My point that I would like to make first is I think that these commodities can be used to produce ethanol and let farmers produce at full production capacity, more efficient, happier, take better care of the land, more soil conserving measures would be used than with the present programs that are in force. So all of us are U.S. citizens and taxpayers, and these programs are very costly to the taxpayers, and taxpayers don't visibly see what they are getting with surpluses in food supplies.

Then we have the people that argue that we are doing away with some of the world's food supply, and again, we are saving all the protein in the processes that we are using.

I do want to congratulate the Congress on their foresight in the way they do, setting up the .programs that were set up in 1979, 1980, in that era, and made some money available for use in the alcohol program.

Our particular situation in Franklyn, we produce 21 million gallons of ethanol per year. This was made possible through a Farmers Home Administration loan guarantee of $32.5 million, and a Department of Energy cooperative agreement on $9.8 million, and as we progressed putting this together, what we have here was basically—I started by myself, I saw I needed some technology, I needed some marketing expertise, and I brought in Chevron U.S.A. for ownership in the corporation, and to provide me with a plant manager and some technical people, and also to market all the ethanol.

They are presently marketing ethanol as an additive to their unleaded regular gasoline in the State of Kentucky, and it is a 10-percent additive and it boosts the octane from 87 to 89 to 90. This has taken the knock and ping out of cars that you presently are buying the super or the supreme gasoline to do away with the knock and the dieseling and these problems; also, cutting down on emissions.

It also has an effect—to go back to your coal problems—where we are located in Kentucky, which, by the way, in your colleague Bill Natcher's area there, we have high sulfur coal—we are using high sulfur coal as our fuel for this plant, and we are using the new Foster-Wheeler fluidized-bed boilers with the lime injected into the boiler bed, and then we are burning the coal on top of the lime, taking out the SO2's, and we are passing the new emission regulations. Therefore, we are finding further uses for the coal as well as for farm commodities.

Now, on an experimental basis, I'm a pilot of some 35 years and I've tried everything in airplanes you can think of—that the FAA did not know about, in most cases. I had my own 3,800-foot strip on the farm and I even ran tractor gas in one of my old airplanes for a while, and I got to having problems with a little coughing every once in a while because the coloring that they added into it was stopping up the carburetion system just a little bit, and so I know there are some problems to be had there.

We did our own experiments. We own a transportation company, also, and I believe it was the winter of 1973 when it was so doggone cold that some of the diesel fuel was jelling in the lines and trucks would shut down when it was below zero. So we tried two different things. We put jet fuel at the rate of 5 percent in some of the trucks, and we did away with the jelling; and then we put 200-proof alcohol in at the rate of 5 percent. We found the 200-proof alcohol we used from November till March for several years in 400 Cummings engines, and we did not have any more jelling of the fuel. And you could definitely see a little more power from these engines.

Well, right now, I have got two that have been running with 5-percent alcohol now that have some 490,000 miles on them and have never had the heads off of them, so I don't think there has been too much damage because usually the life of one of those engines is 500,000 miles.

Now, I don't have all the technical backup that you folks do, but I do know by experience what it will do. We have one 350 General Motors engine that's been running on 25-percent alcohol and 75-percent regular gasoline for some 50,000 miles, and we did take the heads and manifolds and exhaust system off of it and compared it with another engine that had the same service, and it was in much better condition. We put it back together, still using no oil, and they do get rough service because I have a bunch of cowboys there on the farm and driving the trucks over the road, too. So they have had extremely rough service and they do pretty good.

Now, I could tell you what rate of speed those 400 Cummings go down the roadway with a load with that additional alcohol injected in them, but I prefer not to because this is on a public record. But they do move; I'll tell you that.

I feel there is a real opportunity here to use the surpluses now under our situation. We are making 220 tons a day of cattle feed. Some of it goes to hogs; some of it goes to chicken operations. It's a 30-percent protein feed. It's dried down to 11 percent, and it will keep for 1 year if you want to keep it that long. And also we have done some experimental work which wasn't approved by FDA, by the way, on making cookies and different things out of the same material, and people have eaten them; they are extremely good. I started to bring some to this hearing and I thought I might better not do that, so I didn't.

But I think that there are areas that Congress could devote money to taking this product and making granola-type bars and things like that to provide protein for the hungry people around the world that will keep, that you don't have to refrigerate, you don't have to worry about it, and they don't have to cook it. So there are lots of potential there.

We also have a CO_2 plant that we built in conjunction with this. And, by the way, we've got $72 million in this complex right now, and it's computerized, and we are working, counting the guards. And the CO_2 plant, we have got about 145 people all total working on this site, and it is economically feasible—it is using 24,000 bushels of corn per day, 24 hours a day, 7 days a week. We are figuring 333-day operation per year and the rest of it's down time for repairs and maintenance.

But, in summary, I would say ethanol certainly can be the fuel of the future, but it's probably going to take some additional help financially by the Congress in some of the research and development areas, and some of the areas of helping people in the actual farming community to get started in this production of ethanol.

With that, I think I would entertain any questions you would like, and certainly I think it's real good when a farmer can get together with a big oil company and we can produce the quality of material that we are producing. We do not market anything that has over one-half percent water content in it. We meet all the ASTM specs on acids and all these things, and I'm not sure everybody does that. But Chevron insists that we meet all of the specs, and we do.

And we have our own lab there to see—we have hourly check on the quality of materials we produce. So I welcome any of you to come any time to Franklyn, Ky., and actually see it being done, and I'll give you some comparative results. You can test it yourself with some of the vehicles we have around there.

I thank you very much for this opportunity to appear before you with this testimony.

[The prepared statement of Mr. Wade follows:]

THE HONORABLE DAN GLICKMAN, Chairman
Subcommittee on Transportation,
Aviation and Materials

It is certainly a pleasure for me to have the opportunity to present testimony today concerning agriculture, the ethanol industry, and its relation to transportation. This subject has become very important to me because I am a farmer and I am also very deeply involved in the new power alcohol plant located in my hometown of Franklin, Kentucky.

It is evident that the United States has a large surplus of feed grains and other fermentable materials. The government has created programs such as PIK to help alleviate the problem of surplus commodities. Why not use these surplus materials for the fuel so desperately needed by this country. Why not decrease our dependence upon foreign markets for oil and help U.S. taxpayers at the same time by encouraging the farmer to produce rather than encouraging him not to produce and attempting to pay him for the difference with the various programs?

Kentucky Agricultural Energy Corporation was formed in early 1980 by myself and a group of Simpson County, Kentucky, investors with experience in farming, trucking, grain handling and fuel marketing. In January, 1981, Chevron U.S.A. (a subsidiary of Standard Oil of California) joined KAEC principals as a major investor and stockholder. In addition to financial contributions to KAEC, Chevron agreed to provide additional manpower to the project. Chevron also will market the alcohol in Kentucky and other surrounding states.

Ethanol burns cleaner and cooler and cuts down on emission problems. The desired blend of 10% agriculturally derived anhydrous ethanol and 90% unleaded gasoline makes a premium grade fuel. Power alcohol has a high potential for use as an octane booster as well as an extender for motor fuels.

The economic impact of our Power Alcohol Plant will be beneficial to Simpson County as well as the surrounding areas of Kentucky and Tennessee. Using local corn as a feed stock, the project will provide the farmer with a constant market for his product. The source of energy for the plant will be high sulfur coal, trucked in from mines within a 90 mile radius. By-products of the plant are Distillers Dried Grain and Solubles, a high protein livestock feed, and carbon dioxide, which will be utilized by the new CO_2 production facility which has been constructed adjacent to the plant and owned by Airco Industrial Gases.

KAEC presently employs approximately 100 professional and hourly employees on a three shift, 333 day per year anticipated production basis. Additional employment opportunities will extend to farming, transportation, mining and other related industries.

The primary feedstock for KAEC will be corn. According to the 1979 Kentucky Agricultural Statistics and the 1979 Tennessee Agricultural Statistics, fifty-one million bushels of corn is presently being shipped to feed lots and poultry operations in Tennessee, Georgia and Alabama. The plant will utilize over 24,000 bushels of corn per day on a 333 day per year basis. The local availability of corn and local on-farm storage will enable the plant to operate with a one week inventory of on-plant corn storage.

The coal required for steam production is a high sulfur, locally available commodity. Coal usage will be approximately 110 tons per day, and will be supplied by the West Kentucky Coal Mines.

Electrical needs will be provided by Warren Rural Electrical Cooperative (WRECC), a TVA affiliate. WRECC has built an additional substation adjacent to our plant site to provide the power required by KAEC.

Water requirements are being provided by three sources: Simpson County Water District, Arrow Springs and Drakes Creek. The plant and utilities are constructed to use a combination of these water sources.

Our operation was begun because of the current U. S. problem in supplying liquid fuel for transportation and the need to reduce dependence on foreign imports. I continue to feel optimistic that there is a great future for ethanol alcohol in the fuel industry in this great United States.

Thank you very much for this opportunity to appear before you.

James Robert Wade, Sr. President
Kentucky Agricultural Energy Corporation
P. O. Box 657
Franklin, Kentucky 42134

KENTUCKY AGRICULTURAL ENERGY CORPORATION

POWER ALCOHOL PLANT

FRANKLIN, KENTUCKY

Background

For several years, the principals involved in the Kentucky Agricultural Energy Corporation had been investigating the feasibility of a Power Alcohol Plant, employing their experience in related fields and their knowledge of the local agricultural and utility resource base. After several years of preliminary investigation, a site in southern Simpson County was selected for the plant.

Kentucky Agricultural Energy Corporation was formed in early 1980 by James Robert Wade, Sr., and a group of Simpson County, Kentucky investors with experience in farming, trucking, grain handling and fuel marketing. C & I/Girdler (Bechtel Petroleum) of Louisville, Kentucky was asked to prepare a feasibility study for a twenty-one million gallon per year Power Alcohol Plant using the best available process. Following the feasibility study C & I/Girdler proceeded with a complete engineering and construction package for the project.

In January, 1981, Chevron U.S.A. (a subsidiary of Standard Oil of California) joined KAEC principals as a major investor and stockholder. In addition to financial contributions to KAEC, Chevron agreed to provide additional manpower to the project. Chevron also will market the alcohol in Kentucky and other surrounding states.

On November 3, 1980 construction began on the project and produced its first Alcohol on December 20, 1982. Construction included storage and handling facilities for raw materials and finished products, two coal fired boilers and utility system, the process plant, a water treatment facility, and office and administration area, parking, and a road and railroad system. The process building will provide for corn grinding, mash preparation, enzymatic reaction, fermentation, distillation and grain drying. The utility systems will include two boilers and coal handling equipment, boiler feedwater treatment, air compressor system, a cooling tower and an electrical equipment area.

The 180 acre plant site is predominantly rolling terrain, cleared of trees and brush, previously being used for agriculture and grazing. It is bordered by the Louisville and Nashville Railroad and by Route 31-W which provides direct access to Interstate 65. The site is located two miles south of Franklin, Kentucky and four miles north of the Kentucky-Tennessee border. It is situated between Bowling Green, Kentucky, 25 miles north of the site, and Nashville, Tennessee, 40 miles south of the site. Franklin is the county seat of Simpson County and has a population of approximately 8,000. Franklin's economy is based equally on agriculture and industry.

Project Impact

The current U.S. problem in supplying liquid fuel for transportation while reducing dependence on foreign imports has stimulated interest in the production and marketing of ethanol and alcohol blends with gasoline. The desired blend of 10% agriculturally derived anhydrous ethanol and 90% unleaded gasoline makes a premium grade fuel. Power alcohol has a high potential for use as an octane booster as well as an extender for motor fuels.

The economic impact of the Power Alcohol Plant will be beneficial to Simpson County as well as the surrounding areas of Kentucky and Tennessee. Using local corn as a feed stock, the project will provide the farmer with a constant market for his product. The source of energy for the plant will be high sulfur coal, trucked in from mines within a 90 mile radius. By-products of the plant are Distillers Dried Grain and Solubles, a high protein livestock feed, and carbon dioxide, which will be utilized by a new CO_2 production facility being built adjacent to the plant owned by Airco Industrial Gases.

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Process

Process Technology

The process selected by KAEC is the ACR process for cooking, distillation and dehydration developed by John Chambers at Grain Processing Corporation at Muscatine, Iowa. The ACR process incorporates a patented distillation process, high temperature cooking, and energy saving technology. The process is designed to consume 30% of the energy used in conventional distillation.

The KAEC process is designed for making ethanol (power alcohol) via fermentation based on a corn feed stock at a rate of 24,000 Bu/day (1,000 Bu/hr). A yield of 2.5 gallons of ETOH/Bu of corn is expected, thus producing 60,000 gallons/day which is mixed with 3,000 gal/day of gasoline as a denaturant to produce 21 MM gallons/year based on a 333 day operation.

The plant is divided into eight distinct process sections. They are: Corn Storage and Grinding; Mash Preparation and Cooking; Fermentation; Distillation, Dehydration and Alcohol Storage; DDGS Separation, Evaporation, DDGS Drying and Storage; Boiler and Related Operations; Waste H_2O Treatment and Fire Protection.

Corn Storage and Grinding

Corn, brought into the plant via trucks or rail is weighed on a electronic platform scales and dumped into a receiving hopper from which it is elevated and conveyed into Corn Storage Tanks. Corn is unloaded from the Storage Tanks by bottom mounted conveyors, and is discharged into a bucket elevator which transports the corn to a shaker screen and magnet to remove metallic debris then to two grinding mills. The milled corn is then transported by conveyor directly to the Mash Mix Tank where the cooking process begins.

Mash Preparation and Cooking

The Mash Mix Tank is a thouroughly agitated, multi-stage vessel providing 40 min. residence time. Evaporator condensate, and makeup H_2O are flow controlled to this tank for mash slurry makeup. The mash temperature is controlled to approximately 145 degrees F. Alpha amylase (liquefying enzyme) and caustic are added to aid in reducing viscosity and to control pH, respectively.

The mash is pumped from the mix tank through two precookers, in series, and then through a jet heater to attain a temperature of 350 degrees F. The hot mash passes through the pipeline cooker, providing additional residence time. The combination of heat and liquefying enzyme begins the breakdown of starch into dextrins.

The cooked mash is then cooled by flashing in four stages. A Flash Vessel follows each pressure let-down to separate the flash vapor (steam). Flashed vapor from the first two stages is injected into the precookers to heat the mash to above 200 degrees F.

The fourth flash vessel is called the Vacuum Conversion Tank. The mash in the tank is thoroughly agitated and level controlled. A Vacuum is pulled in the vessel to bring the mash temperature down to 185 degrees F. Sufficient additional enzyme is added to the tank to complete the starch to dextrin conversion prior to fermentation.

The mash is pumped to two more flash coolers where the mash is further cooled to 145 degrees F. From there final conversion takes place in two final conversion tanks. With the addition of a second enzyme and retention for about an hour at 145 degrees F., the mash is then pumped to the mash cooler where the temperature is reduced to 90 degrees F. and transferred to the fermenters. The mash preparation and cooking process is designed to obtain a high degree of heat conservation.

Fermentation

After cleaning the fermenters, through the clean-in-place system, and steaming for sterilization, the fermenters are filled with mash. The fermenter is then "pitched" with yeast from the Yeast Tank. Once fermentation begins, the contents of the fermenter are circulated through a cooler to remove the heat generated in the conversion of sugar to ethanol and CO_2. The fermenter temperature is controlled to approximately 90 degrees F. The CO_2 is vented from the fermenter and is passed through a scrubber where it is washed with H_2O for removal of any alcohol. The alcohol/H_2O mixture is then pumped to the beer well and the CO_2 is transferred (sold) to a third party for purification and marketed.

After the fermentation cycle is complete, the agitator is started to suspend the solids and continues to run during pump out to the beer well. The cleaning cycle is started once the fermenter has been emptied. A new fermenter is filled every 6 hours.

The beer well is an agitated tank having a volume of 225,000 gallons. From the beer well, the beer is pumped, under level control, through a series of 4 preheaters to the distillation section where separation takes place.

Distillation & Power Alcohol Storage

The beer passes through a final beer heater to raise the feed temperature to 160-170 degrees F. The heated beer enters the beer still, a column comprised of perforated trays, which is heated by direct injection of steam. The column is operated near atmospheric pressure. The operating philosophy for distillation and the majority of the process is automatic with controls and readouts located in a central control room. Local panels are provided where required.

The bottoms from the still (Whole Stillage) is pumped to the Whole Stillage Tank for further processing. The overhead vapors from the Beer Still, 50/50 alcohol H_2O, are fed into the bottom fo a Rectifying Column. The Rectifying Column bottoms are gravity fed to the Stripping Column where any alcohol and entrainer are stripped prior to discharging the bottoms to waste water treatment.

A 95% alcohol/H_2O mixture is taken off the top of the Rectifying Column and after condensation, is collected and pumped to the Drying Column. The Drying Column utilizes gasoline as an entrainer. Gasoline is pumped from a Storage Tank through a heater and into the Drying Column. The column is operated at essentially atmospheric pressure. The Drying Column overhead is condensed utilizing cooling H_2O piped to a Decanter where the gasoline is separated from the water.

Because the product alcohol/gasoline mix exits the bottom of the Drying Column in a ratio of approximately 95/5, no further denaturing is required. The product is then cooled and sent to two Alcohol Storage tanks. The product is then metered to a tank truck or rail car for shipment.

DDGS Separation, Evaporation, Drying & Storage

Beer still bottoms containing 8-11% total solids is held in the agitated Whole Stillage Tank. The Stillage is pumped to three horizontal centrifuges then two roll presses which separate the feed into two fraction - Wet Cake and Thin Stillage.

The concentrated stillage is approximately 40-50% solids. The syrup is pumped to the Minglers where it is mixed with the residual solid grain prior to final drying.

The grain drying operation is two stages consisting of an initial stage of two steam tube rotary dryers which evaporate approximately 70% of the water and a second stage flue gas rotary dryer which completes the drying to a product with only 10% moisture. The dried grain product is airveyed to storage silos where it is stockpiled for shipment.

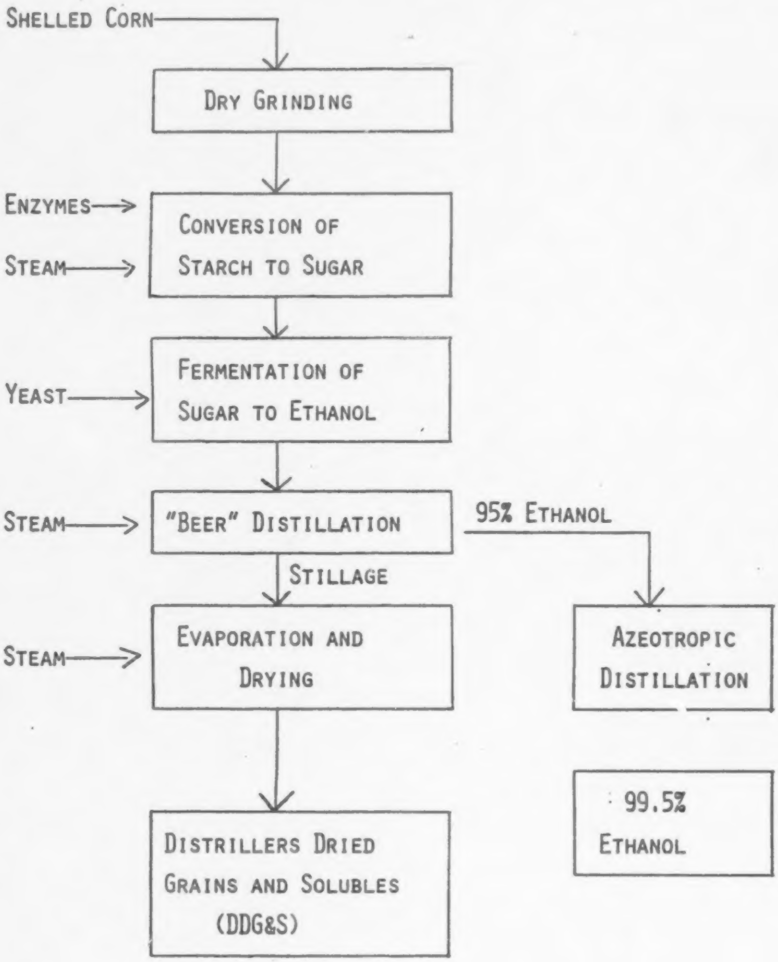
Boilers

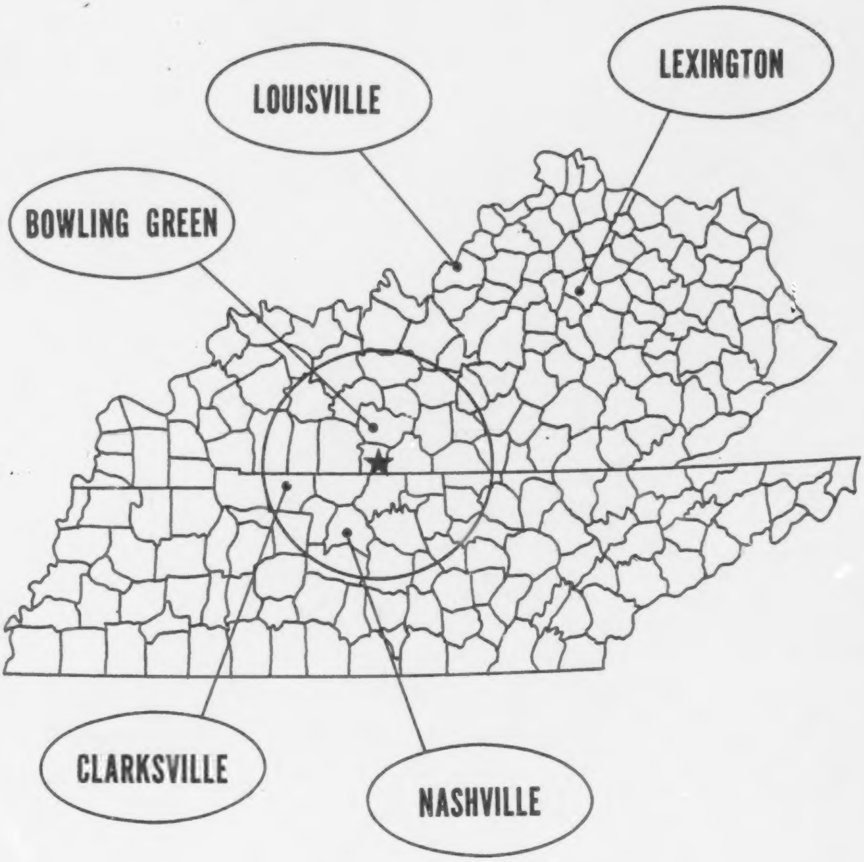
Steam for the plant is provided by two - 60,000=/hr coal fired, fluidized bed, water tube boilers. Saturated steam is generated at 550 psig. The boilers will require approximately 100-110 tons per day of local high sulfur coal (2-5%). The fluidized bed requires limestone to be fed in with the coal and by doing so, removes the SO_2 in the forming $CaSO_4$. Since the SO_2 removal efficiency is 85-90% no additional flue gas scrubbing system for removal of SO_2 is required. The flue gas exits the boiler at 500 degrees F, and, after particulate removal, is utilized to complete the drying of the DDGS (Distillers Dried Grains w/Solubles).

Waste H_2O Treatment

The treatment facility for this plant is designed for all process wastes. An activated sludge waste treatment facility is used. The activated sludge system provides primary treatment for BOD and suspended solids reduction to acceptable permit discharge limits. Design philosophy was aimed at minimum net discharge so that all treated waste water will be reused as cooling water tower makeup.

DIAGRAM "A"
MATERIAL SCHEMATIC


SHELLED CORN
DRY GRINDING
ENZYMES
STEAM
CONVERSION OF STARCH TO SUGAR
YEAST
FERMENTATION OF SUGAR TO ETHANOL
STEAM
"BEER" DISTILLATION
95% ETHANOL
STILLAGE
STEAM
EVAPORATION AND DRYING
AZEOTROPIC DISTILLATION
99.5% ETHANOL
DISTRILLERS DRIED GRAINS AND SOLUBLES (DDG&S)


LEXINGTON
LOUISVILLE
BOWLING GREEN
CLARKSVILLE
NASHVILLE

K. A. E. C.

LOCATION OF AGRICULTURAL SUPPORT

FRANKLIN, KENTUCKY 60-MILE RADIUS

PROJECTED PROCESS DATE

PLANT BASIS -- 333 OPERATING DAYS/YEAR

RAW MATERIAL	APPROXIMATE DAILY		ESTIMATED ANNUAL
Corn	24,000 Bu/day		8,000,000 Bu/yr
Coal	110 T/day		36,300 T/yr
Limestone	32 T/day		10,800 T/yr
Gasoline	3,000 Gal/day		1,000,000 Gal/yr
UTILITIES			
Electricity	90,000 kw-hr/day		30,000,000 kw-hr/yr
Water	250 GPM/day		120,000,000 gal/yr
PRODUCTS			
Power Alcohol	63,000 gal/day		21,000,000 gal/yr
DDG&S	210 T/day		70,000 T/yr
Lime Ash	52 T/day		17,500 T/yr
CO_2	210 T/day		70,000 T/yr
EMPLOYMENT			
Regular Employees			107
Supporting Jobs			270
TRANSPORTATION			
Trucks	85/day	or	28,305/yr
Railcars	30/day		9,990/yr
PAYROLL			
Salaries and Wages			$3,000,000/yr

Mr. GLICKMAN. Thank you. I want to thank you for not only refreshing testimony, but we regret that you didn't bring your cookies with you. We would like to have tried them.

You don't perceive or conceive of any quality control problems in your process? You think that that's no different than any other sophisticated distillation or fermentation process, that you can handle that?

Mr. WADE. We have been able to handle it. All of our equipment is stainless steel and we actually can make beverage alcohol if we were in a position where that's what we had to do.

Mr. GLICKMAN. What would happen to the cost of—I'm looking now at the—because of the drought, the daily change, rapid escalation in the price of some of the feedstock that you are buying—what effect is that going to have?

Mr. WADE. It's tough right now. Now we are still hedged up for another couple of months' operation in good shape. We are looking right now for out-of-condition grain. We can make just about as much alcohol with a No. 5 or sample grade corn as we can with No. 2 corn. Now, we are corn only right now. We can also use barley, wheat, milo, and most anything that will ferment. We can use any operation, the way we built it.

Mr. GLICKMAN. At what price per bushel of corn would you not be competitive, or would you have difficulty selling the product?

Mr. WADE. At $3.70 per bushel, we are getting on the thin edge, I'll tell you that. At the present oil and gasoline prices now, we anticipate there will be changes in those as time goes along.

Mr. GLICKMAN. OK. And let me ask you this: You talked a little bit, Mr. Wade, about the application towards aviation use.

Dr. Wells, I don't know if you have any particular thoughts on whether you think the methanols or ethanols have a great application for aviation use and whether you could foresee the fairly significant demand coming from that sector?

Mr. WADE. I'll take a shot at it first.

I personally am an old pilot, and you've heard there are old pilots and there are bold pilots; but there are no old bold pilots. So I haven't been bold enough since my experience with tractor gas—I haven't tried the alcohol concept on my own airplane. I'd rather to have somebody else to try it and tell me it's OK., and then I'm ready to go.

Mr. GLICKMAN. Mr. Wells?

Dr. WELLS. Yes, sir.

My company's perspective—we have always been a chemical experimental manufacturer in the past, and we really got involved in fuel alcohol use since about last November. But since that time, we have had several of us full time looking into it, and it's been mostly an information gathering, finding out what has been done and educating ourselves rather than active participation. But I can say that our strategy for the future is absolutely dependent on not only aviation becoming an end use, but as I mentioned in my remarks, of part of the crude barrel, you could look at Brazil, to the experience that happened there where they went to alcohol-powered vehicles, but they forgot about the diesel. They took care of the spark ignite bug; they didn't develop, you know, diesel vehicles. They are working on that now a little belatedly. What happened now, they suddenly didn't have diesel any more and they had to export gasoline because they had to have too high or too low crude runs.

So, with this, this doesn't happen. If you take any part of a barrel of crude oil, what it goes to, we want to see applications developing, and from what we have seen—our association with Mr. Paynter and Mr. Cooper and Union Flights—they certainly have some excellent personnel. And we have also been briefed by the National Aeronautics Association and have a proposal before us to get an STC on another engine, on a turbofan. So we are, you know, very active in this area and we absolutely positively believe that alcohol has a role in aviation.

Mr. Glickman. Are you aware of what efforts are being done overseas? You talked about Brazil for a minute. Are you aware of what's being done by the Japanese, West Germans or anybody else, in this area?

Dr. Wells. I'm not aware on aviation, but I am very much aware of what they have going on in other forms of transportation. The Japanese, while they have not made a conscious decision to use methanol as a fuel, that's somewhat related to their own particular needs—to continue to import substantial quantity of crude oil, I think, so they can have appropriate buying power. They have come very far in developing neat methanol-powered vehicles, for example; I think 85 percent more. And I think—I understand Nisson and Toyota both have a model that they could introduce in a very short period of time in a foreign market, including the United States.

West Germany, I know both for diesel applications and for automotive applications, that they are looking at alcohol fuels. They have already had a great deal of experience with what they call M3, which is at the lower end, only 3 percent alcohol. But I know that their automotive manufacturers over there are looking at the upper end of this thing, which is M-90, M-100, something like that. And while they don't have their vehicles out on production yet, simply because there is, you know, not the volume of alcohol available over there—they are an importer in the EC and they are an importer of methanol into the EC. They are certainly preparing themselves for the future, I think.

If you pretty well ask Ford, GM or anyone what are we going to be driving around in the year 2020, I think they are going to say a substantial portion of methanol-powered and ethanol, probably, too, powered vehicles on the highway.

Mr. Glickman. They may say this now, but when this subject first came up they were not encouraging the development of alternative fuels. Really, in all candor, only one auto company, the Ford Motor Co., was out in front on this issue. And now the others have come along. And that, again, reminds me a little bit of the conversation with the prior witness that, you know, if we think we are just going to wait and some miracles will happen, it's not going to happen.

Dr. Wells. I think they are changing. As I said in my material, Detroit Diesel Allison Division, which is General Motors, was 100 percent no additives, methanol-powered coach, which is going to be operating in the Golden Gate Transit Authority's watchful eye, and this is a radical departure for General Motors, who I think who have in the past, I think, talked a great deal about the advantages of conventional diesel.

But I have read an article from the San Francisco Examiner where one of their long-range planning people publicly stated in California that in order to combat the particulates and the emissions problems associated with diesel fuels in California, that GM was willing to develop neat methanol-powered passenger automobiles to replace a specifically—says replace diesel equipment, which is a dramatic turnaround for General Motors, and encourages me a great deal.

Mr. **Glickman**. Mr. Carney.

Mr. **Carney**. Thank you, Mr. Chairman.

Mr. Wade, what is the price of a bushel of corn now?

Mr. **Wade**. We bought some last week for $4.23 a bushel delivered to the plantsite. That's the highest that we have paid, ever, that I know of. We bought it a year ago at this time for $1.89 a bushel. So you see the fluctuation there, and we nailed down a lot of futures back then. Our average price right now is still bringing $2.72, when we swap out the futures, but we are looking at other ways to go.

And, by the way, another point I'd like to make is, we have demand for over three times as much alcohol as we can produce, and it's being accepted real well by the general public. Chevron has put on a real extensive advertising campaign in the State of Kentucky, its TV and news media of all types, and it's really been accepted well. And, of course, it's been being sold at the same price as everybody else's unleaded regular. And when they find out how good it runs, we are really getting a demand for it.

Mr. **Carney**. All your fuel is now being utilized to mix with Chevron, so you have got a gasohol?

Mr. **Wade**. We don't call it gasohol any more, for some reason. That's got all screwed up 2 or 3 years ago, and now it is unleaded regular and enhanced with ethanol, or enhanced unleaded regular. It's a bunch of bull, but it means the same thing.

Mr. **Glickman**. You know, we now talk about taxes as being revenue enhancement.

Mr. **Carney**. Mr. Wells, the methanol that you are providing Union with is a product of what?

Dr. **Wells**. It's a product of, as I mentioned before, synthesis, which is a reaction of synthesis gas. All methanol is syn-gas, since we used to derive it directly from the synthesis of wood. In today's environment, it is cheap to make that synthesis gas from natural gas, from methane, as a cheap, convenient source of hydrogen and carbon. I would say over 90 percent of the methanol made worldwide today is made from natural gas.

Mr. **Carney**. Let's go back to the gas. You are getting that from methane?

Dr. **Wells**. That is correct.

Mr. **Carney**. Where?

Mr. **Wells**. Methane right now is coming from two sources. Two of our plants are on the Texas gulf coast and they are using Texas natural gas. A third plant is in Alberta, Canada. We are beginning to go—search for offshore, less expensive sources of methane. And we have a fourth plant due to come up late next year, where it's a cooperative effort in Saudi Arabia.

Mr. **Carney**. OK. Are you looking into the techniques to utilize methane gas; that is, you would get from, like, landfills and those types of things?

Dr. **Wells**. We are aware that the city of San Diego is going to turn methane gas from its—I think its sanitary landfill—it may be sewage treatment facilities—into methanol, and they hope to do this within the next year or so. We, in turn, developed a process called calrobic, which is now marketed by another company, which utilizes waste chemicals from any industrial source and turns it into methane, which in turn can be turned into methanol. So we are aware of people doing research in this area.

Mr. **Carney**. So I'll ask this question of both witnesses. You both feel very strongly that there would be an availability of alcohol-based, or alcohol fuels, and whether they be methanol or ethanol, for such applications as aviation and automotive applications in the future?

Mr. **Wade**. I certainly feel that way. I think in the farm commodity decision, we certainly have a lot of surpluses there. And I know of the methane availability, and there are, of course, such as sewage and garbage and landfills—there is lots of waste to come up with methane gas, and we have lots of things in this great United States that we are not using to our best convenience.

Mr. **Carney**. And your ethanol, I read here you are producing 21 million gallons of ethanol a year; is that correct?

Mr. **Wade**. Yes, sir. We run 60,000 gallons a day.

Mr. **Carney**. And that's all going for——

Mr. **Wade**. All going for fuel.

Mr. **Carney**. All going for fuel.

Mr. **Wade**. At least, I think it is. Of course, you know, I'm from Kentucky. We have got a lot of moonshiners down there.

Mr. **Carney**. This is an official hearing, and it is being recorded. Just like you didn't want to bring your cookies over here, maybe you didn't want to bring your milk; right?

Mr. **Wade**. I didn't bring you a sample because I didn't know what law I might violate.

Mr. **Carney**. Do you have requests for the ethanol for other applications and you just can't meet them?

Mr. **Wade**. Well, we have been contacted by some of the pharmaceutical people for ethanol, but we are strictly power alcohol for fuel, and so we just refer them to somebody else and go on.

Mr. **Carney**. I see.

Mr. **Wade**. If at a later date, if we can build another addition on it or something, we might be interested in some of that. But right now, the use for fuel looks the best to us, and we are geared to that, and that's where we are going to stay.

Mr. **Carney**. To do this, you are consuming a million gallons of gasoline a year?

Mr. **Wade**. Now, the gasoline now, is used to denature it, and it goes back into the mix, so you don't lose it, you don't waste it, but you use it in the cut to get the last water out and it automatically then goes in with your alcohol and, therefore, it's automatically denatured. And that's the reason I say it's all going for power use, because I don't believe there is anybody here can drink that stuff with gasoline in it.

Mr. **Carney**. And then the coal is used to create the steam you need?

Mr. **Wade**. Right.

Mr. **Carney**. I know we drifted a little from the use of these fuels in aviation, but it was certainly interesting to hear from both of the witnesses about the production end of these fuels and about the future that it has. I appreciate their testimony. It was rather nice contrast between the two witnesses, too, the corporate one and Mr. Wade from Kentucky.

Mr. **Wade**. I've got the country boy image.

Mr. **Carney**. Ye all come back soon now.

Mr. **Glickman**. I have a feeling beneath that country boy exterior there is a pretty smart man.

Thank you both for coming here today.

Mr. **Wade**. Thank you.

Mr. **Glickman**. This concludes today's hearing. I just want to make a couple of comments before we close off. The first, I want to thank the staff—Jeff Irons, for the minority, Curt Stanford, and, of course, Scott Crossfield, who is perhaps the premier aviator of all, who is a member of the staff of this subcommittee. And we are appreciative of the work the staff has done at this hearing.

Without objection, the record will be kept open for 10 working days, if anybody else wants to have a statement included in this record.

Everyone is invited to see the demonstration planes immediately following the hearing at Hedrick Park, which is one-half mile east on Central, and the park is on the right, and the witnesses should be outside each door to be picked up. But others will have to furnish their own transportation out.

I think this has been a useful hearing. I think that after we have had a chance to examine it, the subcommittee may want to make some recommendations in terms of additional actions by either the Federal departments or agencies. But for the most part the purpose of the hearing was to explore and develop and publicize current actions in developing fuels besides the existing ones to propel and fuel airplanes. And as I said in my opening statement, I continue to believe that it would be shortsighted of us to think that the current lack of energy problems, at least on a day-to-day basis, will last forever. They will not. The problems will become severe again.

And while we have different ways that we can deal with this problem, if we want to keep the industry competitive and we want to keep people working in these plants, we have to provide folks that want to buy airplanes with a stable, secure and economical price for the fuel that they are going to put in these airplanes. Otherwise, they are not going to buy them. And I think that that's one of the functions of the hearing—is to explore a variety of issues.

Mr. Carney, do you have any concluding comments?

Mr. **Carney**. Mr. Chairman, I would just like to thank you for the hospitality that we've had out in Wichita. It's been a delight to have an opportunity to come to your city here. Everybody here has treated me extremely well, and I thank you for that, and I commend you for having a hearing of this nature. It certainly was an informative one, and the reason it was informative was because of the witnesses we had.

So I extend my heartful appreciation to these witnesses for coming here, and we look forward to seeing the static displays. And for those of you who took that extra step to bring the materials so we could have the hands-on experience, I again thank you doubly.

Mr. GLICKMAN. We thank you for leaving the beaches of south Long Island to come here to cool Kansas during the month of August. We know that you came here because of the weather. I'm sure everybody is here because of the weather.

The hearing stands adjourned.

[Whereupon, at 1 p.m., the subcommittee adjourned subject to the call of the Chair.]

APPENDIX

NATIONAL AIR TRANSPORTATION
ASSOCIATION
Representing Commercial Aviation Service and Transportation Companies

Founded December 28, 1940

BOARD
OF
DIRECTORS

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Hal S. Spragins III
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Memphis Aero Corporation
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Immediate Past Chairman
Robert H. Showalter
President
Showalter Flying Service Inc.
Orlando, FL

September 19, 1983

The Honorable Dan Glickman
Chairman, Transportation Aviation and
Materials Subcommittee
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Glickman:

The National Air Transportation Association (NATA) is America's representative for air taxi air carriers and ground service and support organizations commonly known as fixed base operators or "FBOs." We appreciate the opportunity to express our views for the record to this Subcommittee on alternative aviation fuels.

Expert witnesses have already covered the technical aspects of alternative aviation fuels, upon whose expertise we will rely. Because of our limited technical expertise, our comments are restricted to the economic and liability aspects of alternative fuels — specifically the use of automotive gasoline (mogas) in aircraft.

In our opinion, the primary force behind the move for mogas use as an alternative aviation fuel is economic, rather than the availability of supply of aviation gasoline (avgas). Pilots frequently ask why avgas is not sold for the same price as mogas. Typically, aviation consumers do not understand that most FBOs' leases with airports require that they remain open for business 12 to 24 hours a day, 7 days a week, provide fuel and ramp services, rest rooms, visiting areas, public telephones, maintenance and other services demanded by pilots. The costs for these so-called "free" services has traditionally been recovered in the retail price of aviation fuel. When the facts are known, however, it is clear to see why aviation gasoline sold at airports is more expensive than motor gasoline sold at service stations.

The same pricing philosophy would hold true in nearly every instance if FBOs sold mogas for use in aircraft. The retail price would be about the same as avgas since the same non-product costs associated with the handling of avgas would apply to mogas. Such factors as personnel costs, quality control measures, facilities and equipment rental, utilities, depreciation, insurance, construction costs and return on investment would all be added to the wholesale price. Add to that the higher handling costs of mogas, resulting specifically from the low turnover of product. Separately, or in combination, these non-product costs result in low profit potential, discouraging most FBOs from selling mogas.

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A recent study of aviation fuel retailers within NATA revealed that less than one percent of the respondents currently sell mogas.

In the same survey, almost three-quarters of the FBO respondents indicated they were extremely concerned about liability exposure if they sold mogas for use in aircraft. Fuel retailers' liability exposure is particularly important considering the less stringent quality control measures taken in the production and distribution of automobile gasoline as compared with aviation gasoline. And, since there is no common agreement between aircraft and engine manufacturers, oil refiners and the Federal Aviation Administration on using mogas in aircraft, FBOs would very likely assume a level of liability for any accidents involving aircraft fueled with mogas.

If, because of the reasons noted above, FBOs do not sell mogas, aircraft owners may themselves bring mogas purchased at automotive service stations onto the airport. FBOs and airport owners are very concerned about the safety hazards associated with the storage of gasoline in containers in hangars, tie down areas and in the trunks of cars by people who lack the training and experience in the handling of hazardous materials. We feel that the high potential to compromise the safety of individuals and the public far outweigh the benefits of this activity. Therefore, we strongly oppose uncontrolled fueling and encourage all airport owners to develop rigid standards to control all types of aircraft fueling activities performed on their airports.

In summary, NATA neither supports nor opposes the use of mogas in aircraft. The number of FBOs selling mogas may increase when all liability concerns are answered, demand for the product increases and there is sufficient profit potential. We remain unalterably opposed to aircraft owners bringing fuel onto the airport and strongly encourage airport owners to assure safety on the airport by setting standards to prohibit this type of activity.

We encourage the Subcommittee to look beyond the technical aspects of this issue and focus on what may be the real driving force: Economics. Since our knowledge on this subject, as it relates to FBOs, is very high, we would be pleased to work with your staff when and if deemed appropriate.

Sincerely,

L.L. Burian

Lawrence L. Burian
President

LLB/sas

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September 6, 1983

Representative Dan Glickman
Congress of the United States
House of Representatives
2435 Rayburn Building
Washington, D.C. 20515

Subject: Aviation Fuels Hearing

At the request of Dr. Kurt Feltner, Associate Dean and Associate Director of the Kansas Agricultural Experiment Station, I attended the hearing on alternative aviation fuels held in Wichita on Monday, August 29. In response to your closing remark soliciting written comments, I would like to offer the following observations.

First, the Subcommittee on Transportation, Aviation and Materials should be commended for it's interest in alternative fuels. All too often, we find ourselves dealing with crisis, rather than anticipating problems and planning responses in advance of the difficulty. The August 29 hearing represents a clear effort by the committee to evaluate the fuel alternatives and gain input for planning purposes.

Alternative fuels, however, are a highly complex issue, involving the technical aspects of fuel performance as well as the social and economic impacts of changing energy sources. In many cases, testimony during the hearing focused on relatively narrow experiences with the end use of the various alternative fuels, with little regard for the deeper impacts such a change in fuel source might have on our society. This was particularly true of some of the comments made on ethanol.

Internal combustion engines run on heat. When predicting engine performance on alternate fuels, the heating value of the fuel will be the primary factor influencing the quantity of fuel used to perform a given amount of work. Based on heating value alone, ethanol would be expected to perform about 65% as much work as gasoline on a "per gallon" basis. However, several secondary factors tend to increase ethanol's value above this level. The most significant of these factors is ethanol's higher octane, which allows it to be used in more efficient engines having higher compression ratios. Other relatively minor positive factors include a slightly higher mole ratio of combustion, slightly higher volumetric efficiency (due to charge cooling) and the ability to burn at leaner mixtures than gasoline. The combined effect of all these factors would raise the value of ethanol to roughly 76% that of gasoline (Schrock, 1980). Burning ethanol in engines is not a new idea, and all of these factors are well documented in the technical literature (Freeman, 1976; Bandel, 1977; and Obert, 1968). In my opinion, the published results of controlled tests are far more reliable than the poorly controlled demonstration results reported during the hearing.

I take strong exception to the reference to grain derived ethanol as "renewable". Substantial fossil fuels are used in the production of grain, both directly in the form of gasoline and diesel fuel for field operations, and indirectly in the form of natural gas for fertilizer and agricultural chemical synthesis. Secondly, fossil fuels are commonly used in the processing and distillation of the ethanol for fuel use. The amount of fossil fuel used in the production of alcohol from grain is a controversial subject, but there is serious question whether the "energy balance" is positive or negative. O'Neal (1980) and Meekhof, et.al. (1980) both concluded that little, if any, net energy is gained by the production of ethanol from grain. Ethanol proponents tend to dismiss such discussion as irrelevent, but I submit that the questionable energetics of ethanol are at the root of it's inability to compete in the fossil fuel market on an unsubsidized basis. Subsidizing fuel ethanol into economic feasibility without correcting the underlying technical problems is at best a temporary measure.

The food versus fuel issue is another complex issue that received only cursory attention during the hearing. On one hand, the claim was made that ethanol from grain will bolster the farm economy by using grain for fuel. Next, the claim was made that ethanol would not conflict with food, since the protein of the original grain still exists in the distillers dried grain. Clearly, the two claims are mutually exclusive. Reality lies between the extremes of the two claims, in that the carbohydrate components of the grain are removed and used for fuel, while the distillers dried grain is placed on the feed market to compete with soybean meal and other protein supplements. Brown (1980) presents a detailed study of the food versus fuel issue.

I found it most discouraging that conservation through redesign was not mentioned during the hearing. Nearly all of Wichita's current single engine aircraft designs originated in the 1940's or 1950's, yet great strides have been made in materials, manufacturing technology, and design methods since that time. Ten years ago, Detroit automakers protested that small, fuel efficient automobiles were not profitable. Later, when it became obvious that Japan would build such cars if Detroit didn't, Detroit somehow found the resources and technology to redesign their products and become competitive again. During the past ten years, the Corporate Average Fuel Economy of Detroit's manufacturers has doubled. If Wichita's offerings had achieved similar improvement in fuel economy, perhaps they would be more salable in today's marketplace. I mention this not to fix blame, but to suggest that a more comprehensive approach to fuel economy, including examination of the airframe, powerplant, and energy source, will be needed to reestablish general aviation's position in the transportation industry.

Farmers have access to immense amounts of solar energy, and I believe that a means will be found to harness that energy for a strong net energy gain. Among the promising approaches being investigated in the Department of Agricultural Engineering are vegetable oils as a diesel substitute, and crop residue gasification. I firmly believe that Agriculture can and will contribute to energy supplies at some point in the future. I do not, however, wish to see Agriculture become "locked in" prematurely to an inefficient means of energy production through the use of heavy subsidies.

Yours truly,

Mark D. Schrock

Mark Schrock
Assistant Professor

cc: Dr. Feltner
Dr. Spillman

References:

Bandel, W. 1977. Problems in the application of ethanol as a fuel for utility vehicles. International Symposium on Alcohol Fuel Technology. November 21-23, 1977. Wolfsburg, Germany. Trans. by U.S. Dept. of Energy. CONF-771175.

Brown, L.R. 1980. Food or fuel: new competition for the world's cropland. Worldwatch Institute. Paper no. 35.

Freeman, J.H., et.al. 1976. Alcohols-a technical assessment of their application as fuels. American Petroleum Institute. Publication No. 4261.

Meekhof, R., M. Gill, and W. Tyner. 1980. Gasohol: prospects and implications. USDA/ESCS Agricultural Economic Report No. 458.

O'Neal, H. 1980. Ethanol production and use. Texas Agricultural Extension Service.

Obert, E.F. 1968. Internal combustion engines. International Textbook Company.

Schrock, M.D. 1980. Using alcohol in engines. Proceedings of Forum on Alcohol Fuels. Feb. 22, 1980. Kansas State University.